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MMS 90-0036

**Offshore Environmental
Studies Program**

Technical Summaries of Selected Atlantic Region Final Reports

Volume 1

MMS

**Offshore Environmental
Studies Program**

Technical Summaries of Selected Atlantic Region Final Reports

Volume 1

Technical Summaries Prepared Under MMS Contracts
14-12-0001-30014 and 14-12-0001-30321 by:

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Availability

The technical summaries contained in this OCS Study were prepared by Continental Shelf Associates, Inc. under contract to the Minerals Management Service (MMS). The summaries were compiled and prepared for publication by the MMS Branch of Environmental Studies located in Herndon, Virginia.

Copies of this publication can be obtained either from the MMS Office of Offshore Information and Publications or the Atlantic OCS Regional Office. The addresses and telephone numbers for these offices are provided below. Questions about individual studies should be addressed to the Branch of Environmental Studies (MS 644), MMS, Department of the Interior, 381 Elden Street, Herndon, VA 22070-4817.

Office of Offshore Information and Publications
Technical Publications Unit
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Preface

The Outer Continental Shelf (OCS) Environmental Studies Program, administered by the Minerals Management Service (MMS) of the U.S. Department of the Interior since 1982, has sponsored hundreds of environmental and socioeconomic studies since its inception in 1973. Many of the research reports resulting from this program consist of several lengthy volumes. Most of the reports are available through the MMS Regional Offices, the National Technical Information Service, and regional libraries, but it is sometimes difficult and expensive to obtain the desired information. Therefore, the MMS initiated a project to summarize this vast collection of data and make the condensed information more readily available to potential users. These technical summaries will enable readers to determine whether they require the original reports. The technical summaries are anticipated to serve the purposes of many users of the information generated by the OCS Environmental Studies Program.

This volume represents the second collection of MMS technical summaries to be published. Summaries of 43 Atlantic OCS Region final reports are included. The first published collection included summaries of 42 Pacific OCS Region final reports. Similar volumes will soon be published for the Alaska and Gulf of Mexico Regions, as well as the Headquarters Office. Additional volumes will be published for the four MMS Regions and Headquarters Office as enough of the completed technical summaries become available.

The summaries are prepared following a standard format designed to provide the reader with a synopsis of administrative and technical information. A map is included when appropriate to show the area of study. In this volume, the summaries are organized in topical sections representing aspects of the OCS Environmental Studies Program. Topics include baseline, biology, protected species, fates and effects (chemistry), geology, other (multidisciplinary projects, conferences, workshops, etc.), physical oceanography, and socioeconomics.

Summarizing information contained in hundreds of lengthy "grey literature" reports is a major undertaking. Many individuals contributed to this effort. Under contract to the MMS, Continental Shelf Associates, Inc. (CSA) furnished a team of scientifically qualified technical writers and editors to produce the tightly written summaries contained in this volume. Their continued attention to detail has resulted in summaries that accurately characterize the scientific findings of the complex, and often lengthy, original reports. Mr. Brian J. Balcom, CSA Project Manager, has provided outstanding leadership throughout the term of this project and his responsiveness to the many changes requested by the MMS has been commendable. His high level of enthusiasm has contributed greatly to the success of this project.

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How-to-Use Guide

This volume contains 43 technical summaries of selected final reports prepared under contracts sponsored by the MMS Environmental Studies Program in the Atlantic OCS Region. The technical summaries are organized in eight topical sections. Within topical sections the summaries are organized chronologically by access number (abbreviated contract numbers). During 1973 to 1978, when the Environmental Studies Program was administered by the Bureau of Land Management, contract numbers included the prefixes CT (contract), IA (Interagency Agreement), and MOU (Memorandum of Understanding). However, the MMS contract numbers are represented by their final 5 digits. Access numbers that include decimals indicate that an individual contract produced a number of final reports that resulted in the preparation of more than one technical summary. In this volume, examples are access numbers 29185 and 29185.2. These examples demonstrate that MMS contract number 14-12-0001-29185 produced two final products that resulted in two separate technical summaries.

Three indexes are provided in this publication to assist the reader. The Key Word Index is an alphabetized listing, with reference to applicable access numbers and topical sections, of all key words contained in the technical summaries. The Report Title Index provides an alphabetized listing of report titles included in this collection of technical summaries with reference to page numbers. The Affiliation Index is an alphabetized listing of the project managers' affiliations, also with reference to page numbers. This index was prepared to provide the reader with a quick reference to the organizations responsible for managing the studies sponsored by the OCS Environmental Studies Program.

Introduction

The OCS Environmental Studies Program was initiated in 1973 to support the U.S. Department of the Interior's offshore oil and gas leasing program. Statutory authorization is derived primarily from three laws: the 1953 OCS Lands Act, the 1969 National Environmental Policy Act (NEPA), and the OCS Lands Act Amendments of 1978. The OCS Lands Act established Federal jurisdiction over the submerged lands of the continental shelf seaward of State boundaries. The Act charges the Secretary of the Interior with responsibility for administering mineral exploration and development on the OCS. Originally, the Secretary designated the Bureau of Land Management (BLM) as the administrative agency for leasing submerged Federal lands and the Geological Survey for supervising exploration, development, and production. All Federal OCS minerals leasing and management activities were reorganized into the Minerals Management Service (MMS) by Executive Order 3071, enacted in January 1982, and amended in May 1982. The functions and mission of the OCS Environmental Studies Program, formerly a part of the BLM, are now a part of the MMS.

The enactment of NEPA in 1969 required all Federal agencies to use a systematic, interdisciplinary approach that ensures the integrated use of natural and social sciences in planning and making decisions for any Federal action or program that may significantly impact the environment. The BLM's response to this mandate assumed the form of comprehensive Environmental Impact Statements based upon information compiled during the various phases of the leasing process. In 1973, the BLM established the OCS Environmental Studies Program to assure that an adequate information base was available so that management could make sound decisions.

The OCS Lands Act Amendments of 1978 established policy for the management of OCS oil and gas activities and for the protection of marine and coastal environments. They also provided the first legislative mandate for environmental studies in support of offshore minerals development. The OCS Lands Act Amendments of 1978 formally recognized the OCS Environmental Studies Program and required that studies begin at least 6 months before anticipated lease offering dates. The goal of the OCS Environmental Studies Program, as established by this Act, is to provide information needed for prediction, assessment, and management of impacts on the human, marine, and coastal environments of the OCS and nearshore areas that may be affected by OCS oil and gas activities. Three specific objectives are recognized to meet this goal: (1) to establish information needed for the assessment and management of environmental impacts on the human, marine, and coastal environments of the OCS and potentially affected coastal areas; (2) to predict impacts on marine organisms that may result from chronic low-level pollution or large spills associated with OCS production, from discharge of drilling muds and cuttings, as well as pipeline emplacement, and from onshore development; and (3) to monitor human, marine, and coastal environments to provide time-series and data-trend information for identification of significant changes in the quality and productivity of these environments.

From 1973 to 1978 the OCS Environmental Studies Program consisted primarily of baseline and monitoring studies. The design of these studies was based upon information assembled through literature syntheses and supplemented by special studies of selected sites or topics of interest. The baseline studies were large-scale multidisciplinary projects designed to characterize the nature, abundance, and diversity of marine animal and plant populations, the physical characteristics of the seafloor and overlying waters, and the concentrations of certain trace metals and hydrocarbons in the water, sediment, and selected organisms before any OCS oil and gas activity in an area. A

series of monitoring studies, in concept, were to follow each baseline study to provide information on changes in measurable environmental characteristics relative to the baseline data as OCS oil and gas activities proceeded.

The baseline approach was criticized by decisionmakers because the program was not providing timely and appropriate information for leasing decisions and by scientists who advised that the marine environment varies too greatly to determine a statistically valid baseline within a reasonable length of time. A major effort was undertaken to restructure the OCS Environmental Studies Program. Information needs of the OCS minerals management decisionmaking process became the thrust of environmental studies planning. A program management document entitled "Study Design for Resource Management Decisions: OCS Oil and Gas Development and the Environment" was published in October 1978. Program guidance presented in this document requires a clear relation between a study and OCS issues and decisions. The Environmental Studies Program continued to evolve with changes evident by a greater balance between prelease and postlease studies, a greater emphasis on generic studies, and the development of postlease monitoring studies.

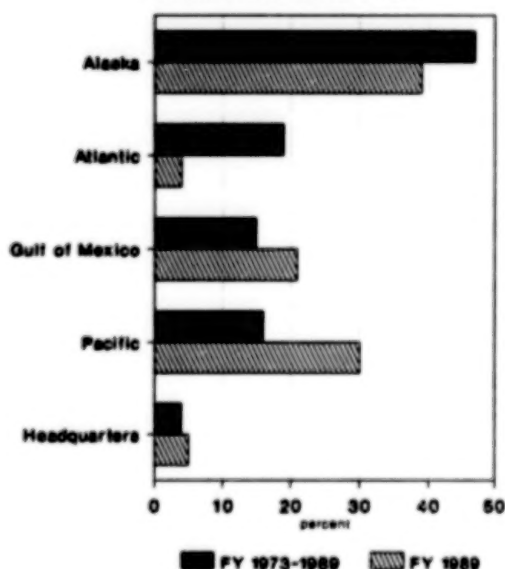
The initial funding of the OCS Environmental Studies Program in 1973 was just over \$300,000. The program is now one of the largest, single agency, mission-oriented oceanographic programs in the Federal Government. Approximately \$490 million have been invested in environmental and socioeconomic studies through fiscal year (FY) 1989. The following figure provides information on the allocation of funds for FY 1989, as well as, the period of FY 1973 through FY 1989 for the four OCS Regional Offices and the Headquarters Office. The following table summarizes the expenditures by study topic for the same time period.

Information generated through the OCS Environmental Studies Program is received in the form of reports, maps, magnetic media, or other records. These represent a significant source of information needed for the many stages of the decisionmaking process involved

in management of OCS resources. Such information is used for development of programmatic Environmental Impact Statements upon which the 5-year OCS oil and gas leasing schedules are based, for development of lease sale Environmental Impact Statements and other NEPA documents, for evaluation of plans for OCS exploration and development submitted by oil companies, and for planning other studies needed by the MMS. In addition, the information produced by the OCS Environmental Studies Program has many other users in State and Federal agencies, academic institutions, and private industry.

To make the vast collection of information more readily available to a wider audience, the MMS initiated a project to prepare technical summaries of all final reports prepared for the OCS Environmental Studies Program. This volume, containing 43 technical summaries of selected Atlantic OCS Region final reports, is the second of several planned preliminary releases of summary

Environmental Studies Program
Spending by Region
fiscal years 1973-1989 and 1989



Environmental Studies Program

Expenditures by Study Topic and Fiscal Years 1973-1989

All Regions
(millions of dollars)

Topic	1973	1974	1975	1976	1977	1978
Air Quality	.0	.0	.0	.13	.03	.03
Baseline	.28	1.19	10.83	16.27	15.3	2.13
Biology	.0	.05	3.04	14.52	9.13	12.44
Protected Species	.0	.0	.19	.28	.56	2.67
Fates and Effects	.0	.0	1.33	3.33	3.87	4.85
Geology	.0	.0	3.67	8.31	6.28	7.13
Physical Oceanography	.0	.0	1.82	10.01	8.33	9.44
Socioeconomics	.04	.12	.45	1.26	.73	2.12
Other	.05	.03	2.76	1.62	.48	.10
Total	.37	1.38	24.08	55.59	44.81	40.92

Topic	1979	1980	1981	1982	1983	1984
Air Quality	.17	.5	.26	.68	.07	.32
Baseline	1.17	1.15	2.13	1.05	.35	.0
Biology	12.15	10.04	5.48	4.72	9.8	10.51
Protected Species	2.34	4.39	3.89	4.82	5.61	2.7
Fates and Effects	1.83	5.0	2.94	3.72	3.06	2.52
Geology	6.28	12.35	10.1	3.96	1.17	1.14
Physical Oceanography	4.14	7.0	8.36	8.76	10.32	8.47
Socioeconomics	3.03	1.95	1.6	1.67	1.97	2.24
Other	.18	2.35	2.75	1.57	1.19	.91
Total	31.30	44.72	37.51	30.95	33.55	28.81

Topic	1985	1986	1987	1988	1989*	TOTAL
Air Quality	.29	1.17	.21	.50	.91	5.25
Baseline	.0	.0	.0	.36	.0	52.21
Biology	9.29	8.26	8.07	9.07	3.92	130.49
Protected Species	5.5	2.29	1.62	3.60	2.71	43.16
Fates and Effects	1.13	.95	2.07	1.36	4.57	42.54
Geology	.94	.18	.15	.18	.0	61.84
Physical Oceanography	6.97	8.1	6.81	5.5	2.84	106.87
Socioeconomics	.91	2.2	1.55	1.03	1.48	24.34
Other	1.27	2.33	2.37	1.47	1.12	22.56
Total	26.29	25.48	22.86	23.06	27.92	492.61

*Individual study data for the NOAA/OCSEAP Interagency Agreement (IA) is not yet available for Fiscal Year 1989. Because of this the \$3,364,700 for the NOAA/OCSEAP IA is not distributed to each topic. The full amount is however included in the Fiscal Year 1989 total.

information. The first volume was published in April 1989 for Pacific OCS Region technical summaries and similar volumes will be published for the Alaska and Gulf of Mexico Regions and the Headquarters Office. As sufficient numbers of technical summaries are completed, additional preliminary release volumes for each office will be published. When technical summaries of all final reports sponsored by the OCS Environmental Studies Program are completed, final summary publications will be prepared on a topical and/or regional basis. Current MMS contractors are required to prepare a technical summary for each final report. These summaries will be compiled and published periodically.

I

BASELINE

Originally, baseline studies included multidisciplinary studies (physical, chemical, biological, and geological oceanography) designed to produce a statistically valid benchmark against which the impacts of Outer Continental Shelf (OCS) activities could be measured. These studies were discontinued in 1978 following a review of the Environmental Studies Program by the National Academy of Sciences.

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STUDY TITLE: Middle Atlantic Chemical and Biological Benchmark Studies - First Year.

REPORT TITLE: Middle Atlantic Outer Continental Shelf Environmental Studies. Vol. I, Executive Summary; Vol. II-A, Chemical and Biological Benchmark Studies; Vol. II-B, Chemical and Biological Benchmark Studies.

CONTRACT NUMBER(S): BLM: CT5-42; MMS: 14-12-0001-29125.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1975; 1976.

COMPLETION DATE OF REPORT: August 1977.

COST(S): FY 1975: \$1,761,426; FY 1976: \$111,712; **Cumulative Project Cost: \$1,873,138.**

PROJECT MANAGER(S): D. Folger (USGS), M. Lynch (VIMS).

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey (USGS); Virginia Institute of Marine Science (VIMS).

ADDRESS: Quisett Campus, Woods Hole, Massachusetts 02543 (USGS); School of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062 (VIMS).

PRINCIPAL INVESTIGATOR(S)*: D. Boesch, R. Byrne, M. Champ, R. Ellison, G. Engle, V. Goldsmith, G. Grant, R. Hugget, J. Jacobson, R. Jolly, H. Kator, M. Lynch, W. MacIntyre, F. Perkins, C. Ruddell, E. Ruzecki, C. Smith, R. Vieri, R. Wetzel.

KEY WORDS: Mid-Atlantic; New Jersey; Delaware; Maryland; Virginia; baseline; biology; infauna; benthos; shelf; slope; canyon; epifauna; histopathology; sediment; hydrography; hydrocarbons; plankton; grain size; nutrients; bacteria; geology; community; suspended matter; trace metals.

BACKGROUND: In 1975, the U.S. Department of the Interior included development of a chemical-biological benchmark program in the Middle Atlantic Bight Outer Continental Shelf (OCS) area as part of the OCS Environmental Studies Program. This report represents information from the first full sampling year (four seasons) completed mid-September 1976.

OBJECTIVES: (1) To provide chemical and biological data to serve as a baseline for assessment of possible changes resulting from oil and gas exploration, development, and production activities; and (2) To provide data and information to enhance the quality of OCS management decisions.

DESCRIPTION: The study region covers about 45,000 km², extending off New Jersey, Delaware, Maryland, and Virginia over the broad continental shelf and upper slope. To provide both the extensive area coverage required for leasing consideration and the intensive coverage desired in the lease area portion of most interest to industry, 51 benthic stations were established as follows: (1) 24 stations (A through F), grouped in 6-4 station clusters primarily concentrated in the outer shelf but extending into central and inner shelf areas, were located in a corridor bounded roughly by 33.5°N Lat and 39.5°N Lat; (2) a 7 station transect (G series) positioned near the northern lease area border (40°N Lat); (3) a 6 station transect (K series) positioned along the southern lease area

borders (38°N Lat); (4) a 6 station transect (L series) positioned off Chincoteague, Virginia between 37°N Lat and 37.5°N Lat, south of the lease area; and (5) 8 stations assigned to continental slope and submarine canyons in the central area. The 24 cluster stations were sampled quarterly. The remaining 27 stations were sampled twice yearly. Nine stations in the central area were for dredge and trawl collection of large organisms (megabenthos) that would be used for histopathological and chemical studies. Wherever possible, these stations corresponded with stations sampled for macrobenthos and sediments. These stations were sampled quarterly. Six water column stations were located on a cross-shelf transect extending from C1 off Atlantic City, New Jersey to J1 on the slope edge. Sampling methodology included: standard meteorological parameters; oceanographic parameters [water temperature, conductivity, dissolved oxygen (DO), light transmission, and light scattering] taken at several levels in the water column; and water samples processed for laboratory analysis of salinity, DO, nitrites, nitrates, total dissolved organic phosphates (micronutrients), particulate and dissolved organic carbon (POC-DOC), and suspended sediments. Biological samples were collected including zooplankton with 60-cm opening-closing bongo systems, neuston with towed nets, macrobenthos with a Smith-McIntyre grab, megabenthos with a small biological trawl and a modified anchor dredge, and foraminifera in sediment cores. Sediment samples were collected and analyzed for grain size, organic carbon, and nitrogen. Trace metals were analyzed in zooplankton, neuston, sediment, megabenthos, and particulate matter. Hydrocarbons were analyzed in sediment, benthic organisms, water samples, surface film samples, zooplankton, neuston, and onboard fuels and lubricants. Histopathological studies were conducted on representative megabenthos. Bacteria was sampled and analyzed in the surface microlayer, surface water (1 m), and sediments.

SIGNIFICANT CONCLUSIONS: Within the study area, cross shelf trends seem to be more distinct than latitudinal trends. The study area waters were characterized by two vertical frontal zones, subdividing essentially three water mass types--the coastal boundary layer, shelf water, and slope water. Cross-shelf patterns in the benthic realm are driven by bottom type and temperature. The ridge and swale topography found on areas of the shelf can cause significant localized differences in parameters.

STUDY RESULTS: Data were interpreted as properties and processes in the pelagic realm (i.e., in the water column) and in the benthic realm (i.e., on or in the bottom). Study area cross-shelf trends in both realms seem to be more distinct than latitudinal trends. Dominant trends seem to be related to water depth or distance from shore, but often environmental factors covary with these parameters. The pelagic realm was characterized by two vertical frontal zones, subdividing three water mass types--the coastal boundary layer, shelf water, and slope water. Frontal zones may be sharp or diffuse and may shift depending on hydrographic conditions. The shelf-slope front is generally more distinct than the coastal boundary layer. Water masses were distinguished by salinity, temperature, and variation in vertical thermohaline structure. Generally, parameters were variable nearshore becoming less variable offshore. The water column on the shelf and slope was vertically stratified. Water temperature below the thermocline was constant and calm most of the year, influenced by a "cold pool" water mass present on the central and outer shelf until fall overturn.

Stratification is maintained by density differences created by generally higher salinity and lower temperature bottom water. Density stratification of slope water was seasonally persistent. Water column seston concentrations were locally variable. Surface water seston showed a clear trend of decreasing offshore. Seston in outer shelf and slope water were primarily phytoplankton (bioseston) whereas mineral particles (abioseston) were dominant nearshore. Trace metals and hydrocarbons in

seston showed no clear trends. Heterotrophic bacteria, coincident with higher nutrient and dissolved organic carbon levels, were more concentrated in the coastal boundary layer. A secondary peak occurred at the shelf break due possibly to observed nutrient enrichment in this area. Zooplankton density was variable but generally decreased towards offshore. Meroplankton abundance showed sharp attenuation away from the inner shelf. Neuston and subsurface zooplankton generally increased greatly offshore. Certain zooplankton species were indicators of coastal boundary layer or oceanic (slope) water and their numbers declined markedly across frontal zones.

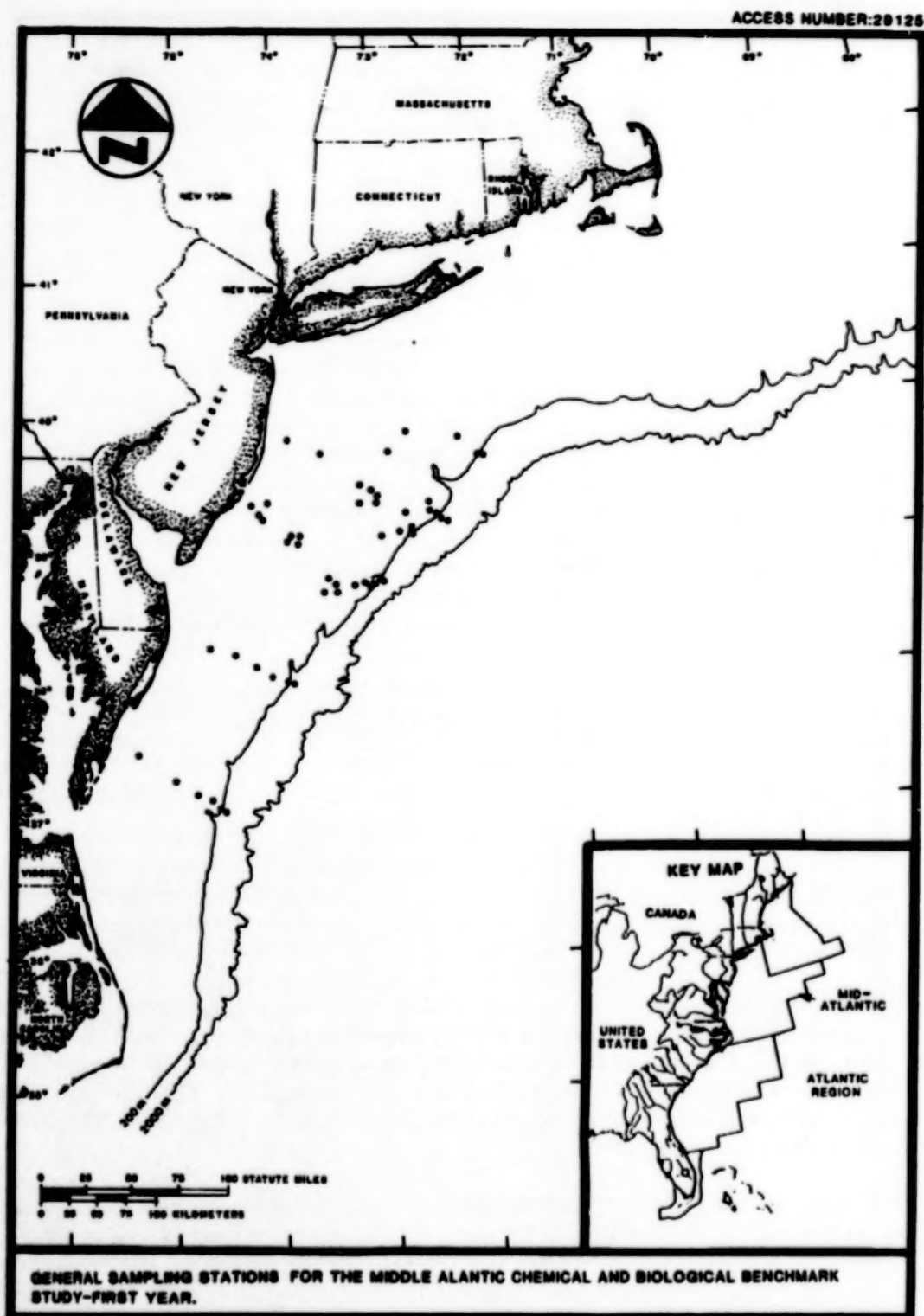
Substrate characteristics and temperature were important features effecting cross-shelf trends in the benthic realm. A dominant shelf bottom feature was the ridge and swale topography running obliquely to the shoreline and extending nearly to the shelf break. These features and others (e.g., terraces and valleys) were formed during the Holocene shoreface transgression across the shelf and contemporary modification by hydraulic processes. This topography has a strong influence on sediment and benthic organism distribution. Study area sediments are characteristically sandy. Hydraulic grading of sediments on the shelf result in medium to coarse sands on the inner shelf and slightly muddy, fine sands on the outermost shelf and break. Sediment distribution and benthic communities are influenced by frequency and severity of sediment movement by waves and current which is related to depth. Sediment movement on the inner shelf is frequent, but on the outer shelf, sediment movement is episodic. Trace metals and hydrocarbons tend to associate with fine sediment and concentrate on the shelf break and slope. Trace metals in megabenthos were variable. High concentrations of heterotrophic bacteria occurred at the shelf break and nearshore due to silt-clay content of sediments and proximity to shore. Foraminifera abundance was variable and affected by local topography. Macrobenthos was most dense on the outer shelf and least dense on the continental slope. Macrobenthos species diversity and richness showed an offshore increase. Shelf break communities had greatest areal richness but continental slope communities had numerical richness.

STUDY PRODUCT(S): Lynch, M. P. and D. W. Folger. 1977. Middle Atlantic Outer Continental Shelf Environmental Studies. Vol. I, Executive Summary. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB281296. Contract No. 14-12-0001-29125. 122 pp.

Lynch, M. P., D. F. Boesch, E. P. Ruzicki, G. C. Grant, and R. L. Ellison. 1977. Middle Atlantic Outer Continental Shelf Environmental Studies. Vol. II-A, Chemical and Biological Benchmark Studies. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB281297. Contract No. 14-12-0001-29125. 747 pp.

Harris, R., C. Smith, R. Bieri, C. Ruddell, H. Kator, and V. Goldsmith. 1977. Middle Atlantic Outer Continental Shelf Environmental Studies. Vol. II-B, Chemical and Biological Benchmark Studies. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB281298. Contract No. 14-12-0001-29125. 556 pp.

**Pl.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Middle Atlantic Chemical and Biological Benchmark Studies - Second Year.

REPORT TITLE: Middle Atlantic Outer Continental Shelf Environmental Studies. Vol. I, Executive Summary; Vols. II-A through II-D, Chemical and Biological Benchmark Studies; Vol. III, Geologic Studies.

CONTRACT NUMBER(S): BLM: CT6-62; MU7-31; MMS: 14-12-0001-29129.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1976.

COMPLETION DATE OF REPORT: July 1979.

COST(S): FY 1976: \$3,629,823; Cumulative Project Cost: \$3,629,823.

PROJECT MANAGER(S): H. Knebel (USGS), E. Bureson (VIMS).

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey (USGS); Virginia Institute of Marine Science (VIMS).

ADDRESS: Quisett Campus, Woods Hole, Massachusetts 02543 (USGS); School of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062 (VIMS).

PRINCIPAL INVESTIGATOR(S)*: D. Baker, D. Bieri, D. Boesch, E. Bureson, R. Byrne, M. Champ, G. Engel, V. Goldsmith, G. Grant, R. Harris, R. Hugget, J. Jacobson, H. Kator, M. Lynch, W. MacIntyre, J. Musick, W. Roller, C. Ruddell, E. Ruzecki, C. Smith, R. Wetzel.

KEY WORDS: Mid-Atlantic; North Carolina; Virginia; Maryland; Delaware; New Jersey; New York; baseline; biology; infauna; benthos; shelf; slope; geology; epifauna; histopathology; sediment; hydrography; hydrocarbons; trace metals; plankton; grain size; nutrients; bacteria; geology; community; suspended matter; fish.

BACKGROUND: The Middle Atlantic Outer Continental Shelf (OCS) was recognized as an area of interest for hydrocarbon exploration following a lease sale conducted in August 1976. In response to this interest, the U.S. Department of the Interior funded a multidisciplinary environmental survey to characterize the area biologically, chemically, physically, and geologically. This information was needed for the prediction, assessment, and management of impacts on the OCS that may be caused by exploratory drilling activities.

OBJECTIVES: (1) To summarize temperature, salinity, dissolved oxygen, and micronutrients during four sampling seasons; (2) To characterize the water column in terms of zooplankton, neuston, bacteria, particulate trace metals, and dissolved and particulate hydrocarbons as they relate to each other and temporal, spatial, and hydrographic variability; (3) To characterize the dominant infauna, epifauna, bacteria, foraminifera, and sediment characteristics in relation to spatial, temporal, and

hydrographic variability; (4) To describe the histopathology of selected epifaunal and infaunal species and discuss histopathological conditions in relation to hydrocarbon and trace metal concentrations; (5) To discuss temporal and spatial hydrocarbon degradation potential of microbial sediments in surficial water and sediments; (6) To extend the Virginian Sea Wave Climate Model for the region from Cape Hatteras, North Carolina to Long Island, New York; (7) To measure the rate of sediment mobility over the seabed and monitor resultant changes in bottom morphology and texture; (8) To determine the concentration, distribution, and flux of suspended particulate matter in the water column; (9) To determine the nature and distribution of high molecular weight hydrocarbons in the near-surface sediment at selected locations; and (10) To evaluate geotechnical properties of bottom and subbottom sediments and their potential hazard to oil and gas development.

DESCRIPTION: The study area covers about 45,000 km² of the OCS and slope off New Jersey, Delaware, Maryland, and Virginia. Sampling stations, established during year one, were located in clusters and along transects within six areas chosen to represent bathymetric zones and/or areas reflective of oil and gas development. Twenty-four stations were located in six clusters, each containing four stations in an area bounded by 38.5°N Lat and 39.5°N Lat. A seven station transect was positioned along the northern border (40°N Lat) of the lease area, a six station transect was positioned along the southern border (38°N Lat) of the lease area, a six station transect positioned off Chincoteague, Virginia between 37°N Lat and 37.5°N Lat, and eight stations were positioned on the continental slope or in or near submarine canyons in the central area. Water column samples included temperature, salinity, dissolved oxygen, organic carbon, bacteria, zooplankton, and neuston. Benthic collections made using a Smith-McIntyre grab, anchor dredge, and trawl included macrobenthos, megabenthos, meiobenthos, and foraminifera. Sediment samples were analyzed for grain size, organic carbon, nitrogen, bacteria, trace metals, and hydrocarbons. Megabenthos were analyzed for trace metals and hydrocarbons. Histopathological analyses were performed on various fishes and invertebrates. Geological sampling cruises were conducted from October 1976 through September 1977. Sampling during these cruises included expendable bathythermographs, conductivity/temperature/depth meter casts, nephelometer/transmissometer casts, suspended matter samples, seismic reflection/side-scan sonar, vibracores, grab samples, tripods, and submersible dives.

SIGNIFICANT CONCLUSIONS: Cross-shelf trends in biological, physical, geological, and chemical parameters were evident in both the pelagic and benthic realms. Many environmental factors covary with depth across the shelf in a seaward direction, and these factors were responsible for observed biological or chemical trends. Sediments were generally stable with respect to potential structure siting. No evidence of petroleum contamination was found in benthic organisms.

STUDY RESULTS: Hydrographic conditions during fall of 1976 revealed that a tongue of cold water was present at the surface and moving into the study area from the north. Warmer water was present below the cold water. Three distinct subsurface zooplankton communities were present across the shelf: a coastal community, a central-outer shelf community, and a shelf-edge/slope community. Neuston collections revealed a predictable coastal assemblage and an unpredictable shelf edge community. The surface layer was important to juveniles and larvae of many fish and invertebrate species. Meroplankton abundance decreased across the shelf in a seaward direction. Dissolved aliphatic hydrocarbon concentrations ranged from 0.004 to 114 ug l⁻¹; dissolved aromatic hydrocarbons ranged from 0.012 to 259 ug l⁻¹. No seasonal trends were evident. Particulate aliphatic hydrocarbon concentrations ranged from 0.0001 to 1.88 ug l⁻¹; particulate aromatic hydrocarbons ranged from 0.001 to 0.02 ug l⁻¹. Some seasonality was noted. In zooplankton, aliphatic hydrocarbons ranged from 2.0 to 3,218 ug g⁻¹ and aromatic hydrocarbons

from 2.2 to 650 $\mu\text{g g}^{-1}$. Bacteria in the microlayer were not enriched relative to subsurface samples. Trace metals concentrations in the water column were generally highest in the coastal boundary layer and decreased seaward across the shelf. Barium and vanadium concentrations were low. Cadmium, lead, and zinc were found mainly in the leachable fraction, while chromium and iron were unleachable. Trace metal levels in zooplankton were highly variable with no definite spatial or temporal trends evident.

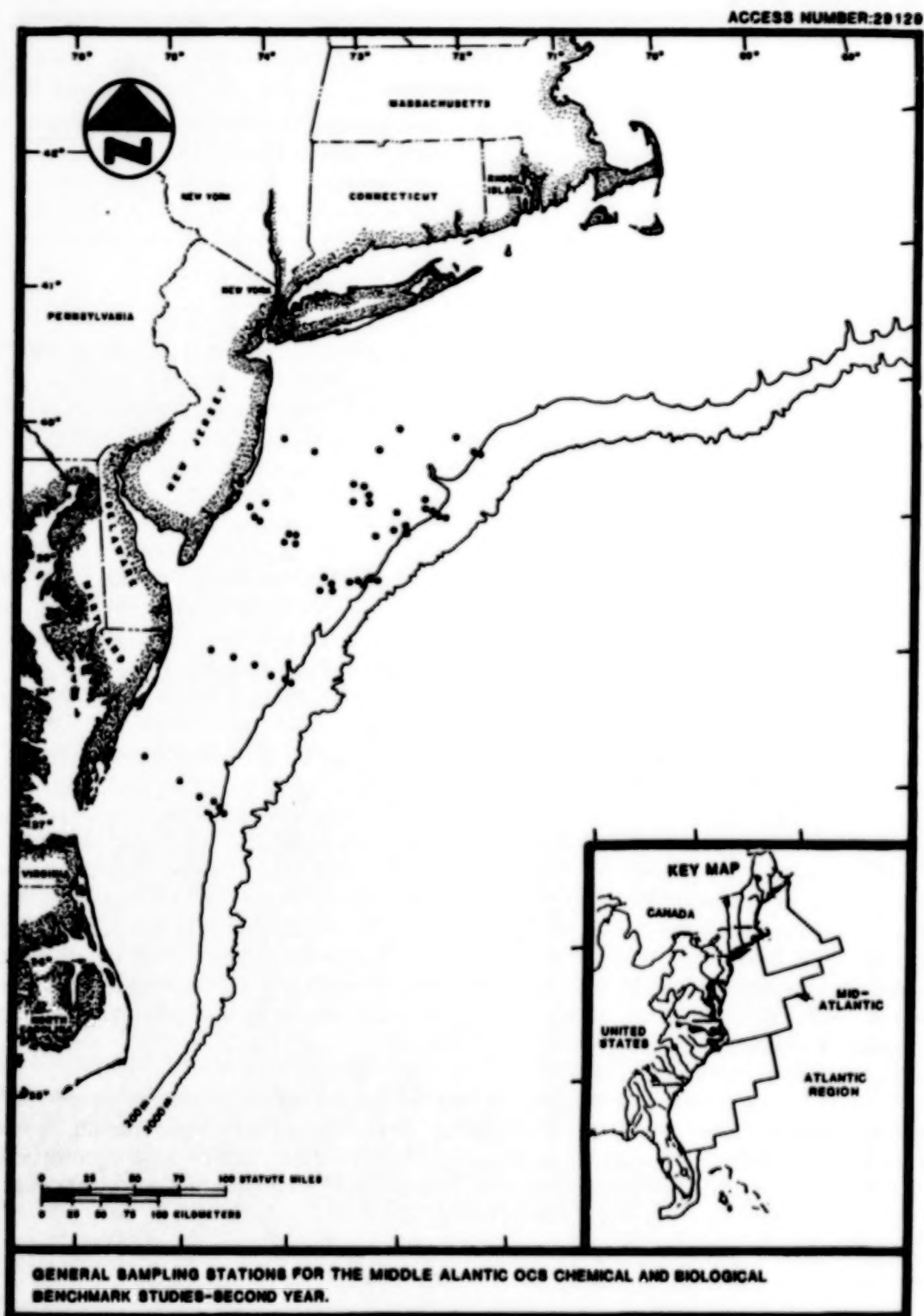
Sediment texture and distribution took the form of swales and ridges. Most shelf sediments are medium to coarse sand with fine muds typifying the shelf break and slope. Organic carbon was closely related to the distribution of silt/clay. Sediment trace metal concentrations (leachable and total) increased seaward across the shelf and were greater in topographic depressions. No seasonal trends were observed in trace metals levels. Sediment levels of aliphatic and aromatic hydrocarbons also increased seaward across the shelf.

Foraminiferal density ranged from 10 to 5,500 organisms per 20 cm^3 . Foraminifera were roughly classified into inner and central shelf zone, an outer shelf zone, and a shelf break zone. Meiofaunal densities ranged from 59 to 1,123 organisms per 10 cm^3 . Nematodes numerically dominated the meiofauna, comprising 40 to 80% of the individuals collected. Harpacticoid copepods were the second most abundant organism, representing 5 to 30% of the individuals collected. Polychaetes constituted 40 to 60% of the macrobenthic individuals. Other groups included amphipods, echinoderms, and molluscs. Megabenthos collected by dredge and trawl was numerically dominated by decapod crustaceans, echinoderms, and bivalve molluscs. Species diversity of both macrobenthos and megabenthos generally increased with depth. Minor faunal differences in both macrobenthos and megabenthos occurred over small distances within the broad scale patterns in relation to shelf topography. Demersal fishes collected by trawl included three migratory groups based on seasonal distribution. Temperature and depth were the most important factors controlling the distribution of fishes on the shelf. Stomach content analyses indicated that demersal fishes prey mainly on benthic invertebrates, but not necessarily the most abundant species. Trace metals concentrations in the benthos were quite variable. Some evidence of sediment contamination was found, particularly in sand dollars. Hydrocarbon levels in benthic organisms were low, with no evidence of petroleum contamination.

Bottom current conditions were relatively calm during spring and summer months. Net bottom flow on the continental shelf was toward the southwest. Small-scale bed forms rapidly formed in response to wind-driven flow during large storms. Total suspended particulates in surface and near-bottom waters were highest during spring months. Bottom sediments on the OCS were resuspended periodically, possibly by internal waves. The clayey sediments tested were heavily overconsolidated, with adequate shearing resistance and low compressibility, presenting no unusual hazard to facility siting.

STUDY PRODUCT(S): Burreson, E. M. and H. J. Knebel (eds.). 1979. Middle Atlantic Outer Continental Shelf Environmental Studies. A final report by the Virginia Institute of Marine Science and the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Vol. I (Executive Summary)-NTIS No. PB81174740; Vols. II-A - II-D (Chemical and Biological Benchmark Studies)-NTIS Nos. PB81174757, PB81174765, PB81174773, and PB81174781; Vol. III (Geologic Studies)-NTIS No. PB81174799. Contract No. 14-12-0001-29129.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic OCS Benchmark Study FY 1977.

REPORT TITLE: South Atlantic OCS Benchmark Program, 1977 Report. Vol. 1, Executive Summary; Vol. 2, Technical Program and Management; Vol. 3, Results of Studies of Georgia Bight of North Atlantic Ocean; Vol. 4, An Atlas of Normal Histology and Histopathology of Benthic Invertebrates and Demersal Fishes.

CONTRACT NUMBER(S): BLM: CT7-02; MMS: 14-12-0001-29130.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1977.

COMPLETION DATE OF REPORT: July 1979.

COST(S): FY 1977: \$4,055,342; Cumulative Project Cost: \$4,055,342.

PROJECT MANAGER(S): D. Adams, M. May, III.

AFFILIATION: Texas Instruments, Inc.

ADDRESS: MS 349, Dallas, Texas 75265.

PRINCIPAL INVESTIGATOR(S)*: L. Atkinson, R. Barber, P. Betzer, B. Coull, R. George, V. Henry, S. Herman, C. Oppenheimer, B. Sen Gupta, J. Staiger, K. Tenore, M. Tripp, H. Windom.

KEY WORDS: South Atlantic; Georgia Bight; North Carolina; South Carolina; Georgia; Florida; baseline; biology; benthos; histopathology; hydrocarbons; trace metals; shelf; slope; epifauna; plankton; bacteria; hydrography; seasonality; suspended matter; infauna; fish; benthic photographs.

BACKGROUND: American society has intensive resource utilization; foremost among these is petroleum. United States petroleum demands have exceeded domestic output causing partial dependence on foreign production. The potential of impending energy shortages emphasizes the need to increase domestic output. The Outer Continental Shelf (OCS) is a valuable petroleum source. With the onset of exploration and exploitation of the OCS area comes the need to preserve the integrity of the environment. To accomplish these goals, the Bureau of Land Management (BLM) established the OCS Environmental Studies Program; as part of this program, the BLM initiated the South Atlantic OCS Benchmark Program (SABP). SABP was implemented to provide environmental data to comply with requirements of the OCS Lands Act of 1953 and the National Environmental Policy Act of 1969. This report was meant to serve as a baseline source of information for any further oil-related research in the Georgia Bight area.

OBJECTIVES: (1) To determine concentration of high molecular weight hydrocarbons (HMWHC) and selected trace metals in water, sediment, zooplankton, and selected macroepifauna; (2) To evaluate variation in benthic and zooplankton communities; (3) To enumerate heterotrophic microorganisms of the surface film, near surface, and sediments and examine the relationship to hydrocarbon presence; and (4) To measure and describe water column chemistry.

Access Number: 29130

DESCRIPTION: The study area was the Georgia Bight offshore of North Carolina, South Carolina, Georgia, and northern Florida between Cape Fear, North Carolina and Cape Canaveral, Florida. Fifty stations were established along seven transects aligned perpendicular to the shore and spaced rather evenly from north to south. Each transect crossed the inner, middle, and outer shelf zones. Stations were grouped and sampled for specific data requirements (e.g., epifauna, water chemistry). Each station was sampled during four periods of the year, beginning 31 January 1977 and ending 29 November 1977. The program was designed to investigate the marine environment and delineate trends in nutrient concentration, various community compositions, hydrography, sediment types, and other natural variables.

Sampling methodologies for all program phases from air/sea interface, water column, and benthic environment are described. Surface-film samples were collected for measurements of hydrocarbon concentrations and determination of microbial community structure and activity. Surface-film HMWHC were collected with a 0.25 m² Teflon disk. Microbial samples were collected by millipore filters and then cultured to enumerate, isolate, and identify dominant microorganisms. Zooplankton and microbes were quantified to study hydrographic, chemical, and biotic conditions of the water column. Temperature, salinity and chemical constituents including those relating to metabolic activity (e.g., chlorophyll *a*) and adverse conditions (e.g., hydrocarbons) were measured. Zooplankton were collected with 202 and 505 μ m mesh nets. Microbial samples were collected in a Niskin bag sampler. Seawater for particulate and dissolved HMWHC analysis was collected in 90-l water bottles. Particulate, dissolved organic carbon, and total trace metals samples were collected in 9-l Go-Flow bottles. Water samples for Winkler dissolved oxygen determination were collected in 5-l Niskin bottles mounted on a rosette sampler. Water column profiles were done by conductivity/temperature/depth (CTD) cast using a Plessey 9400 CTD sensor system. Salinity samples were collected at near bottom, mid-depth, and near surface using Niskin bottles, then measured using a Plessey 6230N salinometer. Micronutrient samples were collected in Niskin bottles. Chlorophyll *a* samples were taken with Go-Flow bottles. Transmissometer/nephelometer profiles were done at each station of each seasonal cruise. Suspended particulate material samples were collected with PVC water bottles in a standard hydrocast configuration. Seafloor samples for granulometry, meiofauna, foraminifera, macroinfauna, microbes, HMWHC, trace metals, and total organic carbon were taken with either a box corer or a Smith-McIntyre grab. All previously mentioned samples were subsampled from the cores, except macroinfauna. Laboratory analysis provided information concerning the concentrations of seawater micronutrients (Autoanalyzer), chlorophyll *a*, dissolved oxygen, and particulate and dissolved organic carbon. Analysis for HMWHC and trace metals in seawater, sediment, and biota was also done. Demersal fish and epifaunal invertebrates were collected by a 45-ft semiballoon otter trawl. Animals collected were used for chemical and histological analyses and taxonomic identification. During box coring, bottom photographs were taken to assist in benthic community description. Statistical analyses examined potential relationships in the data and determined significance.

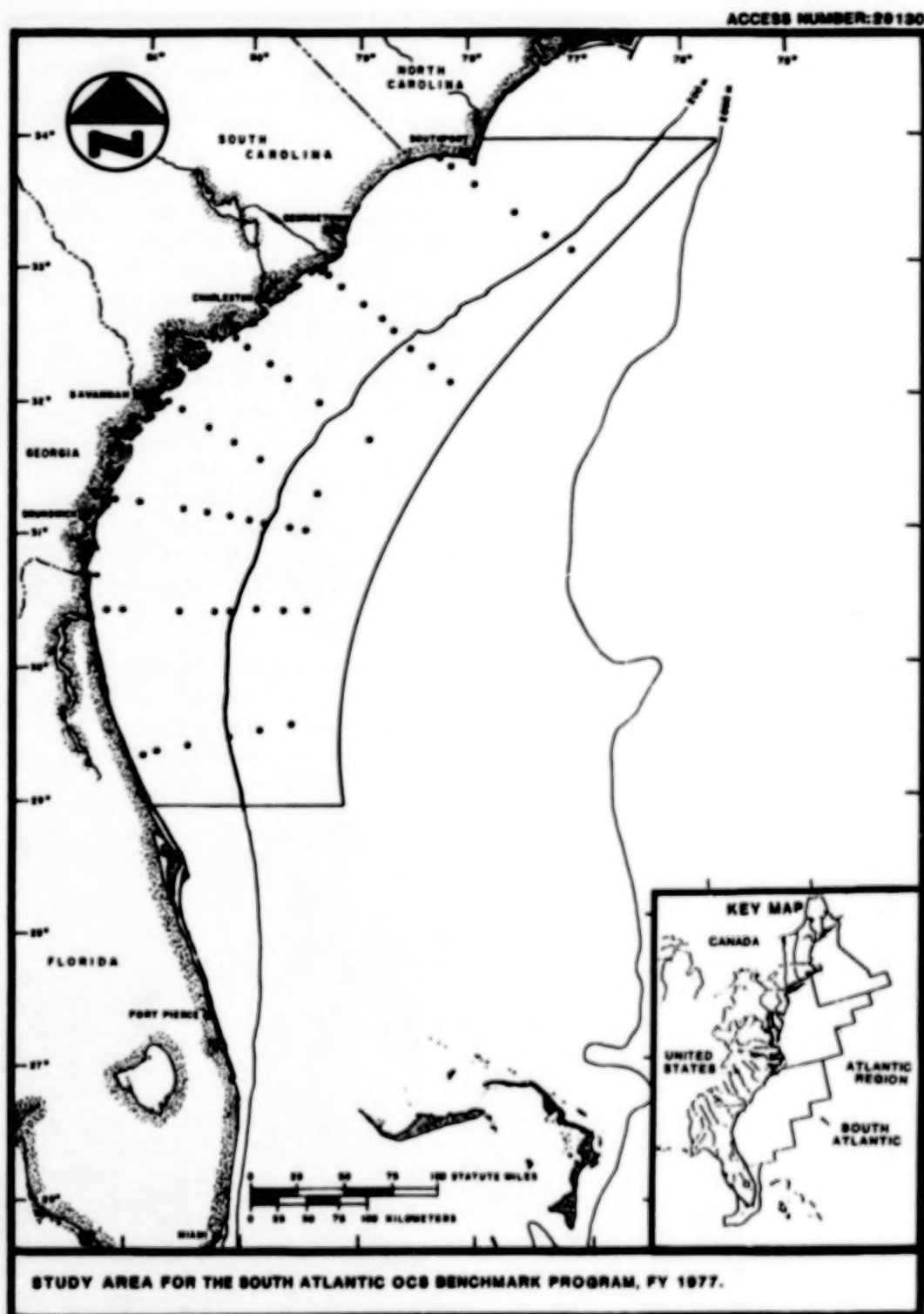
SIGNIFICANT CONCLUSIONS: Quarterly sampling clearly defined seasonal progression along the study area. Oceanic conditions are predominantly influenced by freshwater runoff and Gulf Stream intrusions onto the shelf. High nutrient and chlorophyll *a* values identified a persistent upwelling feature within the study area. Analyses for hydrocarbons in sediment, zooplankton, benthic fauna, and demersal fish gave little evidence of petroleum contamination. No seasonal or regional trends were apparent from trace metal analyses. Zooplankton community assessment indicated that calanoid copepod associations may be used to determine water mass mixture. The Georgia Bight shelf environment has sand bottom areas of low epifaunal biomass and hard-bottom outcrops.

supporting healthy epifauna and fish assemblages. Macroinfauna within the study area can be characterized as having high species diversity and low biomass due to low nutrient input and unfavorable sediment conditions. Familial meiofauna identification limited the delineation of assemblages and correlations with various physical parameters. Some foraminifera species appeared suitable as indicator species to determine changes in the state of the benthic environment. Testing of microbial hydrocarbon degradation capacity showed that degradation ability was reduced during low temperatures, indicating that fall and winter degradation of any introduced hydrocarbons would be severely reduced.

STUDY RESULTS: The continental shelf region of the Georgia Bight was divided into an inshore region, mid-shelf region, and the outer-shelf/upper-slope region. Continental runoff appeared to be retained inshore, accounting for the high sediment silt/clay fractions and nutrients favorable to biotic activity. The mid-shelf region was impoverished of nutrients, probably due to scouring and sediment transport. The outer region had intermediate nutrient conditions, showing the effects of enrichment by Gulf Stream intrusion. Sediment chemistry did not indicate any higher-than-normal conditions. Variations in number of hydrocarbon-using bacteria positively correlated with changes in HMWHC concentrations. Bacterial density was inversely proportional to distance from shore. Hydrocarbon-using bacterial cultures could degrade South Louisiana crude oil and decane. Low temperatures inhibited petroleum degradation capabilities. Biotic community structure was correlated to hydrographic and sediment conditions. Zooplankton density peaked during summer. The zooplankton community was highly diversified and dominated by copepods. Benthic species diversity was high in the study area. Seasonal changes in density and community composition were evident for the macroinfauna and demersal fish. Histological analyses showed animal parasites to be quite common. Functional and structural responses due to parasites were minimal. Incidence of parasitic infestation showed seasonal variation.

STUDY PRODUCT(S): Texas Instruments, Inc. 1977. South Atlantic OCS Benchmark Program, 1977 Report. Vol. 1, Executive Summary; Vol. 2, Technical Program and Management; Vol. 3, Results of Studies of Georgia Bight of North Atlantic Ocean; Vol. 4, An Atlas of Normal Histology and Histopathology of Benthic Invertebrates and Demersal Fishes. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Contract No. 14-12-0001-29130. 4 Vols.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



II **BIOLOGY**

Biology studies describe the distribution and interactions of benthic and pelagic communities and populations. These studies also describe the biological aspects of fishes, birds, turtles, and nonprotected species.

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STUDY TITLE: South Atlantic Hard Bottom Study.

REPORT TITLE: South Atlantic Hard Bottom Study.

CONTRACT NUMBER(S): BLM: CT8-25.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978.

COMPLETION DATE OF REPORT: June 1979.

COST(S): FY 1978: \$235,948; Cumulative Project Cost: \$235,968.

PROJECT MANAGER(S): R. Stevens, Jr.

AFFILIATION: Continental Shelf Associates, Inc.

ADDRESS: P.O. Box 3609, Jupiter, Florida 33458.

PRINCIPAL INVESTIGATOR(S)*: D. Gettleton, T. Neurauter.

KEY WORDS: South Atlantic; Georgia Bight; biology; geohazards; hard-bottom; videotapes; photographs; survey; geophysical; faunal zones; epifauna.

BACKGROUND: Hard-bottom areas in the Georgia Bight support valuable recreational and commercial fisheries and are considered sufficiently sensitive and unique so as to require protection from possible deleterious effects of oil and gas drilling operations. Stipulations for Oil and Gas Lease Sale 43 required that geophysical data collected during routine geologic hazards surveys of each lease block be interpreted for hard bottom within 1,820 m of proposed drillsites. To evaluate the adequacy of geophysical techniques in identifying hard-bottom areas, the Bureau of Land Management selected four blocks from those offered in Sale 43 for comparative study using geophysical and remote photographic methods.

OBJECTIVES: (1) To determine whether geologic hazards survey records would be adequate for delineating hard-bottom areas in the Georgia Bight; (2) To characterize substrates comprising hard bottom through petrographic analyses; and (3) To identify epibiota and demersal fishes associated with hard-bottom areas.

DESCRIPTION: Four lease blocks in the Georgia Bight were characterized during September-October 1978 using a combination of geophysical and remote photographic methods and collections of biological and geological samples. The blocks included James Island Area Blocks 198 (32 to 33 m depth), 380 (44 to 194 m depth), and 463 (44 to 78 m depth); and Brunswick Area

Block 912 (29 to 35 m depth). Each block was initially surveyed using a recording fathometer, side-scan sonar, and subbottom profiler. The survey grid consisted of east-west lines spaced at 150-m intervals and north-south tie lines at 1,000-m intervals. Following preliminary interpretation of these results, areas of suspected hard bottom were examined using a towed television/still camera system. Bathymetric and geophysical records, videotapes, and photographs were examined to describe and map the substratum and associated biota. Rock samples were collected at several stations within each block using a Benthos rock dredge and preserved for later analyses. Representative pieces of the samples were examined in thin section under a petrographic microscope to describe and characterize the major lithologies present. Biological dredge samples encompassing a towed distance of about 100 m each were collected in several hard-bottom areas in each block using a Kahlsico triangular dredge. Samples were preserved and specimens were later identified to the lowest possible taxonomic level. Normal and inverse cluster analyses were conducted for samples from each block and from all blocks using the Czekanowski coefficient and flexible sorting methods.

SIGNIFICANT CONCLUSIONS: Results of geophysical and remote photographic surveys showed that hard-bottom areas could be successfully mapped through the conservative interpretation of side-scan sonar records and the identification of areas of apparent outcropping of subbottom reflectors by the subbottom profiler. Geophysical techniques were least successful in delineating small, discontinuous patches of hard bottom and in distinguishing exposed hard-bottom areas from those that were covered by a thin veneer of sand. Visual inspection of the bottom was necessary to map small patches of hard bottom, to distinguish exposed vs. sand-covered hard bottom, and to describe the abundance and composition of associated epibiota.

STUDY RESULTS: Bathymetric data were not adequate to identify hard-bottom areas, except where ridges or scarps were present or where depressions were clearly associated with hard-bottom areas.

Petrographic analyses of 43 rock samples showed that the hard bottom was principally a Recent to Subrecent biostromal reef. Six lithologic types (sandstone, biomicrite, sandy biomicrite, biosparite, biolithite, and algal biolithite) were identified from dredge samples. No significant variations in their distribution in rock samples were noted between the four blocks.

Examination of videotapes and color photographs of the bottom revealed 10 distinct biological assemblages, each of which was described by its characteristic organisms. Four assemblages were noted in James Island Area Blocks 380 and 463, the most distinctive and abundant being typified by dense tube mats formed by the gregarious polychaete, *Phyllochaetopterus socialis*. Three assemblages were described from James Island Area Block 198 and two from Brunswick Area Block 912. The latter appeared to have the lowest abundance of epibiota of the four blocks studied. In general, abundance of epibiota appeared to be higher in areas of exposed hard bottom than in areas that were covered by a thin veneer of sand.

A total of 499 taxa (including 33 fish species) were collected in 68 dredge samples from hard-bottom areas. James Island Area Block 198 had the highest number of taxa (274), followed by James Island Area Blocks 463 (257) and 380 (214), and Brunswick Area Block 912 (71). Major groups of organisms collected were Porifera (sponges), Cnidaria (hydroids, corals, anemones, sea feathers, and sea fans), Bryozoa, Ascidiacea (sea squirts), Chlorophyta (green algae), Phaeophyta (brown algae), and Rhodophyta (red algae). Many species collected were tropical (Caribbean/West Indian) forms. Results of cluster analyses for samples within each block revealed some groupings, but

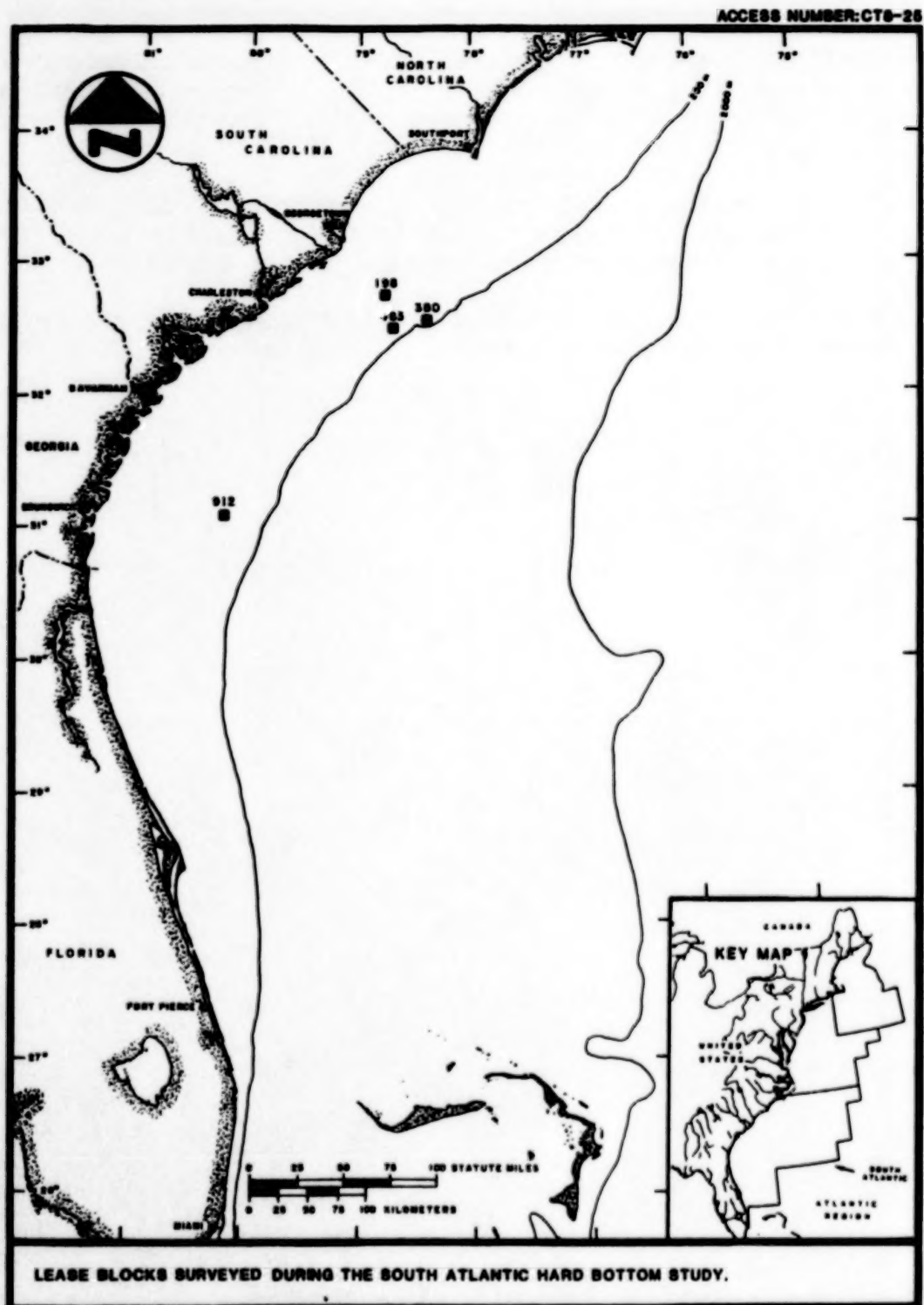
these were believed to reflect sampling artifacts. Cluster analysis of samples from all four blocks indicated that James Island Area Block 198 was most biologically distinct from the others and that James Island Area Blocks 380 and 463 were the most similar to each other in composition.

STUDY PRODUCT(S): Continental Shelf Associates, Inc. 1979. South Atlantic Hard Bottom Study. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB300821. Contract No. AA551-CT8-25. 356 pp.

Gettleson, D. A., R. A. Hammer, and R. E. Putt, Jr. 1982. Geophysical and biological seafloor mapping of four oil and gas lease blocks in the South Atlantic Georgia Embayment. In: Oceans '82 Conference Record, Marine Technology Society, Washington, D.C., pp. 803-808.

Gettleson, D. A., N. W. Phillips, and R. M. Hammer. 1985. Dense polychaete (Phyllochaetopterus socialis) mats on the South Carolina continental shelf. Northeast Gulf Science 7(2):167-170.

**Pl.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: A Benthic Recolonization Study under Simulated Oil Spill Conditions in the Mid-Atlantic Region.

REPORT TITLE: Experimental Colonization of Crude Oil Contaminated Sediments by Benthos on the Middle Atlantic Continental Shelf.

CONTRACT NUMBER(S): BLM: CT8-32; MMS: 14-12-0001-29135.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978.

COMPLETION DATE OF REPORT: April 1981.

COST(S): FY 1978: \$560,712; Cumulative Project Cost: \$560,712.

PROJECT MANAGER(S): E. Bureson.

AFFILIATION: Virginia Institute of Marine Science.

ADDRESS: School of Marine Science, College of William and Mary, Gloucester Point, Virginia 23062.

PRINCIPAL INVESTIGATOR(S)*: D. Alongi, R. Bieri, D. Boesch, M. Bowen, J. Boyer, M. Champ, P. deFur, G. Gaston, H. Kator, W. MacIntyre, L. Schaffner, C. Smith.

KEY WORDS: Mid-Atlantic; New Jersey; biology; colonization; benthos; sediment; meiofauna; macrofauna; grain size; biodegradation; hydrocarbons.

BACKGROUND: Effects of oil exploration and development on biotic communities of the eastern U.S. Outer Continental Shelf (OCS) are of primary environmental concern. In an attempt to provide experimental data for predicting possible impacts, the U.S. Department of the Interior funded a study to conduct field experiments on recolonization of oil contaminated sediments by benthic organisms. This report details the design, execution, and results of those experiments.

OBJECTIVES: (1) To develop and refine techniques for conducting in situ experiments involving exposure of oil-contaminated sediments under OCS conditions; (2) To assess colonization of macrobenthos and meiobenthos following catastrophic disturbance in Middle Atlantic outer shelf habitats; (3) To determine effects of petroleum hydrocarbon contamination on colonization; (4) To determine qualitative and quantitative changes in petroleum hydrocarbons incorporated in natural sediments under in situ conditions; and (5) To assess responses of microbes capable of degrading petroleum hydrocarbons.

DESCRIPTION: The first study phase involved development of a surface activated deployment and recovery system (SADRS). Each SADRS array consisted of a 1.53 m² by 20.3 cm high stainless steel base. This base held four fiberglass boxes that were 47.5 cm² by 15 cm deep. A 1.5-m high tubular stainless steel quadripod above the base supported a lifting ring and an acoustic release buoy system. Dacron covers for the boxes fell into place upon retrieval of the arrays. Experimental arrays were deployed at three sites located on the OCS off New Jersey: A5 (39°21.5'N lat, 72°37.0'W long, 118 m), B3 (39°21.0'N lat, 73°02.1'W long, 72 m), and B6 (39°22.5'N lat, 73°02.0'W

long, 54 m). Experimental design included three control and three treated (oiled) arrays at each station. Control arrays consisted of four replicates (boxes) of previously collected sediment from each of the three sites that was frozen repeatedly to render it azoic. Oiled arrays contained sediment treated similarly but mixed with Prudhoe Bay crude oil. Three boxes contained 250 mg oil per kg of sediment. The fourth box was subdivided; one side contained 50 mg kg⁻¹ and the other contained 2,500 mg kg⁻¹. Prior to array deployment at each station, nine Smith-McIntyre grabs were taken, six for biological (meiofauna and macrofauna) analyses and three for chemical (total organic carbon and hydrocarbon) and grain size analyses. Grain size was determined by sieve separation, pipette analysis, rapid sand analyzer, and Coulter electronic particle analyzer. Total organic carbon was determined by infrared analyzer. Hydrocarbons were identified using gas chromatography and gas chromatography/mass spectroscopy. Meiofauna and macrofauna were stained with rose bengal and subsequently sorted into major taxa. Meiofaunal and macrofaunal community structure was analyzed using diversity (Shannon-Weaver), rarefaction, evenness, and species richness indices. Reciprocal averaging ordination was used to compare grabs and boxes.

SIGNIFICANT CONCLUSIONS: Hydrocarbon contamination did not affect colonization of azoic sediments by macrobenthos or meiobenthos. Degradation of petroleum hydrocarbons in the sediments was minimal, despite persistent populations of petroleum degrading bacteria. Technical problems limited recovery of one control and one oiled array from two sites. Sediment erosion and artificial effects hindered the experiments.

STUDY RESULTS: The arrays were in place for 10 months. Corrosion of cables and other parts of the experimental apparatus limited recoveries to one rather than three as planned. Sediment was eroded from the containers by wave induced currents. Fouling organisms that were attracted to the structures included hydroids, caprellids amphipods, and young scallops. Larger animals used the experimental apparatus as a refugium (e.g., hakes, *Urophycis* spp., cancid and galetheid crabs).

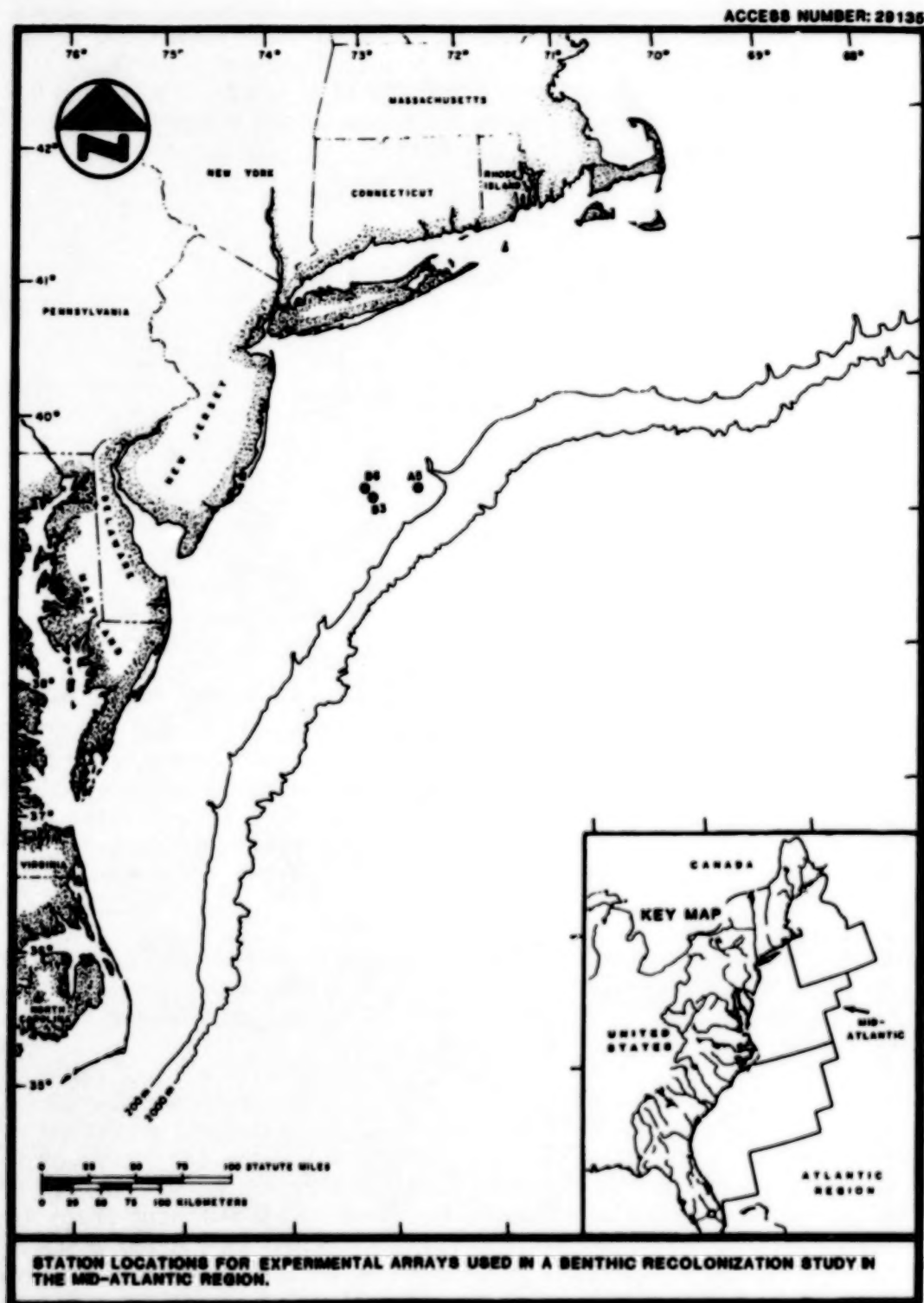
In general, colonization of azoic sediments by macrobenthos proceeded at a similar rate reported for natural OCS communities of the Middle Atlantic Bight. The colonization rate observed at the shelf break station was slightly lower than that of the shelf proper. Long-lived species that rely on planktonic larval dispersal were slower to establish populations than those with effective short-range dispersal (e.g., brooding amphipods, and polychaetes). Meiofaunal density and dry weight biomass were lower in all experimental boxes than in the natural community (246 per 10 m² vs. 34 per 10 m²). Nematodes comprised between 82 and 94% of the total meiofaunal abundance. Copepods, ostracods, polychaetes, and bivalves were also present. No significant differences existed between mid-oiled and control recoveries, but low and high oiled boxes had low meiobenthic densities. Colonization of oiled sediments by meiobenthos was not appreciably altered in oiled sediments, however, overall colonization was slower than previously reported. Lack of significant change in community composition between control and oiled treatments suggests a response to physically mediated conditions.

Petroleum degrading bacterial populations increased in sediments contaminated with crude oil. Biodegradation was limited to the oxygenated upper centimeters of sediment, and in general, weathering of crude oil was slow. As much as 91% of the added oil remained; some toxic components of oil (methylnaphthalenes and methyl phenanthrenes) persisted in moderate concentrations after the 295-day exposure period. Erosion may have been responsible for some losses. Low environmental temperatures, incorporation of oil into sediments, and oxygen and

nutrient limited biodegradation were contributing factors of reduced weathering. The shelf break station retained more oil than the mid-shelf station.

STUDY PRODUCT(S): Boesch, D. F., E. M. Bureson, L. C. Schaffner, H. I. Kator, C. L. Smith, D. M. Alongi, M. A. Brown, and P. O. deFur. 1981. Experimental Colonization of Crude Oil Contaminated Sediments by Benthos on the Middle Atlantic Continental Shelf. A final report by Virginia Institute of Marine Science for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB81223570. Contract No. AA551-CT8-32. 180 pp. + app.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Canyon Assessment Study in the Mid- and North Atlantic Areas of the U.S. Outer Continental Shelf.

REPORT TITLE: Epifaunal Zonation and Community Structure in Three Mid- and North Atlantic Canyons.

CONTRACT NUMBER(S): BLM: CT8-49; MMS: 14-12-0001-29164.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978.

COMPLETION DATE OF REPORT: January 1980.

COST(S): FY 1978: \$612,180; Cumulative Project Cost: \$612,180.

PROJECT MANAGER(S): B. Hecker.

AFFILIATION: Columbia University.

ADDRESS: Lamont-Doherty Geological Observatory, Palisades, New York 10964.

PRINCIPAL INVESTIGATOR(S)*: G. Blechschmidt, P. Gibson, B. Hecker.

KEY WORDS: North Atlantic; Mid-Atlantic; Baltimore Canyon; Lydonia Canyon; Oceanographer Canyon; fates and effects; photographs; biology; physical oceanography; slope; canyon; faunal zones.

BACKGROUND: Advances in photographic sampling techniques and submersible vessels have made quantitative surveys of canyon biota possible. Such surveys are necessary when evaluating environmental consequences of resource development in submarine canyon systems of the Atlantic Outer Continental Shelf (OCS). This study was initiated to investigate and describe faunal characteristics of canyon and slope areas off the northeastern United States. The information collected contributes to the baseline data needed to properly manage environmental resources.

OBJECTIVES: (1) To examine in detail the faunal assemblages from three submarine canyon systems; (2) To provide a historical survey of canyon and slope fauna from previously collected photographic data; and (3) To predict possible impacts on slope and canyon faunal communities associated with resource exploration and development.

DESCRIPTION: Three canyons were studied in detail: Baltimore Canyon in the Mid-Atlantic; and Lydonia and Oceanographer Canyons in the North Atlantic. Depths surveyed were 100 to 1,100 m in Baltimore Canyon, 100 to 900 m in Lydonia Canyon, and 400 to 1,800 m in Oceanographer Canyon. Photographs were taken from a camera sled towed along the walls and axis of each canyon. Dredge and core samples were collected when possible to provide voucher specimens and sediment. Temperature, salinity, current velocity, and acoustic profiles were also recorded. Photographs were subjected to quantitative slide analysis using a scaled grid with 1 m² quadrats and were examined for species abundance, composition, and percent cover of substrate type.

Individual species and total faunal densities (number per 100 m²) were summed within 100-m depth intervals. Classification (cluster) analysis and principal components ordination were employed to objectively discern community patterns and species co-occurrences. Results were compared with historical information that consisted of photographic data taken during 76 submersible dives and 33 still camera lowerings in slope and canyon areas from Hatteras, North Carolina to Georges Bank at depths from 100 to 3,200 m. A taxonomic synopsis of soft corals collected, details of navigation and sampling protocol, and a literature review of submarine canyon geology were included as appendices.

SIGNIFICANT CONCLUSIONS: Submarine canyons located along the continental margin of the northeastern United States harbor diverse and unique faunal communities. Assemblages were comprised of anemones, corals, crustaceans, echinoderms, fishes, polychaetes, and sponges. Species density and composition were related to depth, latitude, and substrate type. Preponderant filter feeders (corals and sponges) found within the canyons may act as indicators of environmental alteration.

STUDY RESULTS: Three major faunal zones were identified: shelf and upper slope (100 to 400 m) numerically dominated by crabs (Cancer borealis and Munida valida) and demersal fishes; mid-slope (500 to 1,300 m); and lower slope (1,500 m) numerically dominated by demersal fishes (i.e., Synaphobranchus kaupii) and echinoderms. Faunal density was high in the shelf and upper slope zone of Baltimore and Lydonia Canyons due to high concentrations of the quillworm Hydroidocia artifex. Peak faunal density in Oceanographer Canyon occurred between 1,700 to 1,800 m as a result of high concentrations (253 per 100 m²) of Ophiomusium lymani. Coral diversity and abundance were lowest in Baltimore Canyon, with Lydonia Canyon being much richer and numerically dominated by Eunephthya florida. Coral communities in Oceanographer Canyon were diverse, with Paramuricea grandis and Acanthogorgia armata being most abundant. Other common corals included Anthothela grandiflora, Anthomastus agassizii, Desmophyllum cristagalli, Distichoptilum gracile, and Pennatulaculeata.

Community analyses did not identify any discrete species assemblages, suggesting that dominant species were independently distributed. Ordination was effective in associating samples with depth zones. In general, fauna was more variable in shallower than deeper zones. Species replacements occurred with depth, but variation could be associated with substrate type.

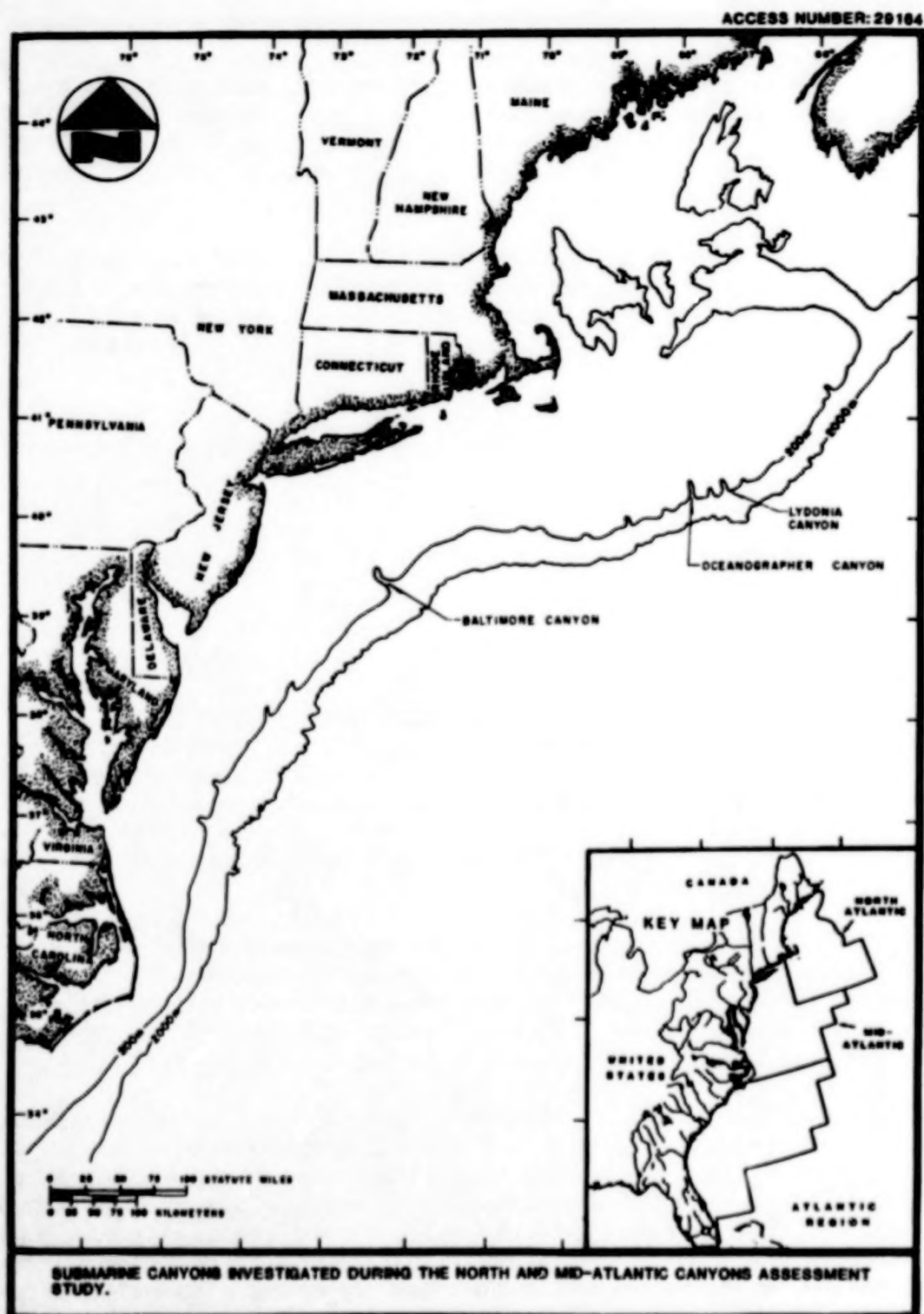
Substrate characteristics for the three canyons reflected differences in geographical location. Oceanographer and Lydonia Canyons, occurring southeast of Georges Bank, exhibited similar geological properties; fine grain sediment predominated on the walls and along the thalweg; rock outcrops and glacial erratics were prevalent. Baltimore Canyon was in a different depositional environment—one of net sediment accumulation. Outcrops, talus, and boulders were buried and less common. Carbonate contents of Oceanographer and Lydonia Canyons were also similar. Average carbonate values for these canyons were consistently lower than those found in Baltimore Canyon.

Survey results corroborated findings from historical information. Faunal densities were highest on the shelf and slope-rise boundary. Higher faunal densities were noted in canyons than on slopes. Canyon walls were described as unique habitats. Substrate complexity determined distribution and abundance of sessile species. Noted faunal associations were the ophiurid Asteromyx loveni in gorgonian colonies; Ophiomusium lymani at the base of coral colonies; and the crab Cancer borealis with the anemone Cerianthus borealis.

Predictions of environmental impact on canyon and slope fauna by resource development activities are not complete. Environmental correlates contributing to observed faunal distribution patterns are not adequately known. This hampers predictions of location and abundance of particular species. Canyons support diverse assemblages of filter feeders (especially corals) that are sensitive to changes in suspended particulate matter that promote deleterious abrasion and excessive mucous production. Suspended matter may explain the sparse coral populations found in Baltimore Canyon, an area of active sedimentation. Both Oceanographer and Lydonia Canyons support diverse coral communities due to low net sedimentation and greater exposed substrate. Coral populations and communities can serve as indicators of environmental stress caused by alterations of suspended matter.

STUDY PRODUCT(S): Hecker, B., G. Blechschmidt, and P. Gibson. 1980. Canyon Assessment Study: Epifaunal Zonation and Community Structure in three Mid- and North Atlantic Canyons. A final report by Lamont-Doherty Geological Observatory for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB8115589. Contract No. AA551-CT8-49.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic Living Marine Resources Study, Year I.

REPORT TITLE: South Atlantic OCS Area Living Marine Resources Study. Vols. I through III.

CONTRACT NUMBER(S): BLM: CT9-27; MMS: 14-12-0001-29168.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1979; 1980; 1981.

COMPLETION DATE OF REPORT: October 1981.

COST(S): FY 1979: \$531,704; FY 1980: \$206,643; FY 1981: \$857;
Cumulative Project Cost: \$739,204.

PROJECT MANAGER(S): V. Burrell, Jr.

AFFILIATION: Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department.

ADDRESS: Box 12559, Charleston, South Carolina 29142.

PRINCIPAL INVESTIGATOR(S)*: D. Blizzard, B. Boothe, D. Calder, C. Harris, D. Knott, T. Mathews, G. Sedberry, F. Stapor, R. Van Dolah, E. Wenner.

KEY WORDS: South Atlantic; biology; North Carolina; South Carolina; Georgia; Florida; biology; hard-bottom; hydrography; videotapes; photographs; epifauna; fish; seasonality; shelf.

BACKGROUND: Widespread areas of hard bottom on the continental shelf offshore the southeastern United States are important to commercial and recreational fisheries of the region, but the ecology of these areas is poorly known. The region has been opened to oil and gas exploration, and areas of prime industry interest often coincide with outcroppings of sedimentary rock that support abundant sessile epibiota and bottom fishes. This study was funded to provide a better understanding of such "live-bottom" habitats so that potential impacts of oil- and gas-related activities could be assessed and minimized.

OBJECTIVES: (1) To characterize invertebrate and fish communities associated with representative live-bottom habitats on the continental shelf offshore the southeastern United States; (2) To characterize food habits of selected fish species of commercial or recreational importance; (3) To conduct a limited assessment of bottom topography and substrate type; and (4) To evaluate potential impacts of oil- and gas-related activities on live-bottom organisms.

DESCRIPTION: Four representative live-bottom stations were chosen in each of three depth ranges (inner shelf, 19 to 27 m; middle shelf, 28 to 55 m; and outer shelf, 56-100 m) on the continental shelf offshore North and South Carolina, Georgia, and northeastern Florida. Nine stations offshore South Carolina, Georgia, and Florida were sampled during winter (January-March) and summer (August-September) 1980; the three stations offshore North Carolina were sampled only during summer. Sampling at each station generally included: (1) profiles (10-m depth intervals) of water column temperature, salinity, transmissivity, and dissolved oxygen, and a light penetration (Secchi

depth) measurement; (2) three 20-min transect surveys using a towed television system; (3) collection of 25 color still photographs each at 1- and 3-m heights above the bottom (0.5 and 3.0 m² areal coverage, respectively); (4) diver surveys (inner and middle shelf stations only) to measure bottom relief, collect rock samples, and photograph fishes and epibenthos; (5) trawl sampling of fishes and other nekton using a 40/54 fly net (3 day and 3 night tows of 1 km each); (6) deployment of baited fish gears (Antillean S-traps, vertical longlines, and manual snapper reels); (7) collection of juvenile fishes using an epibenthic sled (two 5-min night tows); (8) dredge sampling of epibiota and rocks using a heavy-duty Kahisico rock dredge (two 0.1-km tows); and (9) collection of five samples of small epibiota and infauna in sediments overlying hard bottom using 0.1-m² suction (inner and middle shelf stations) or Smith-McIntyre grab (outer shelf stations) samplers.

All samples and data were processed and analyzed to produce physical and biological descriptions of the stations and to elucidate spatial and seasonal trends. Physical descriptions were based on data from diver and television surveys and petrographic analyses of rock samples. Benthic epibiota were characterized by analysis of television and still photographs and data from dredge, trawl, and suction/grab sampling. Numerical classification and reciprocal averaging ordination techniques were applied to dredge, trawl, and suction/grab data; diversity (Shannon index) and evenness (Pielou's J') values were calculated and dominance-diversity curves plotted only for the suction/grab data. Fish populations were described (biomass and abundance) on the basis of data from trawls, baited fish gears, television and diver surveys, and epibenthic sled sampling. Stomach contents of selected fish species were analyzed to determine the composition and inter-species overlap of fish diets.

SIGNIFICANT CONCLUSIONS: Live-bottom areas were typified by expanses of sand-covered hard bottom and scattered outcrops and ledges of low to moderate relief (generally <2 m). Outcrops were most common at outer shelf stations, which were located on a series of discontinuous ridges (remnants of ancient reefs) that extend from offshore North Carolina to northern Florida. Bottom coverage by epibiota averaged 60 to 100% for most stations. Both tropical and warm-temperate forms of invertebrates and fishes were common. Species composition of live-bottom communities varied in relation to depth and, to a lesser extent, latitude and season. Sponges contributed most of the attached biomass (wet weight) at stations offshore South Carolina, Georgia, and Florida, and macroalgae contributed most at stations offshore North Carolina. Abundance of bottom fishes at live-bottom stations was higher than reported for soft-bottom habitats; enhanced abundance and diversity of fishes reflects in part availability of numerous food organisms and shelter associated with live-bottom habitats. Offshore oil- and gas-related activities could have deleterious effects on live-bottom organisms, primarily through smothering or burial of epibiota; however, the presence of platforms and other structures could have favorable effects by increasing the amount of available habitat.

STUDY RESULTS: Bottom temperatures ranged from about 12 to 29°C on the inner shelf, 15 to 25°C on the middle shelf, and 15 to 19°C on the outer shelf. Salinities were generally >35 ppt except at a few inner and middle shelf stations that were affected by river runoff during winter. Dissolved oxygen levels were consistently high (generally <4 ml l⁻¹). Water clarity measurements showed no consistent patterns; transmittance ranged from 38 to 94%, and Secchi depth from 6 to 31 m.

Substratum relief ranged from <0.5 to about 2 m. Live-bottom coverage ranged from about 60 to 100% at most stations and exhibited no consistent geographic trends. The incidence of rock outcrops ranged from 5 to 40% and was highest at outer shelf stations, which are located along a

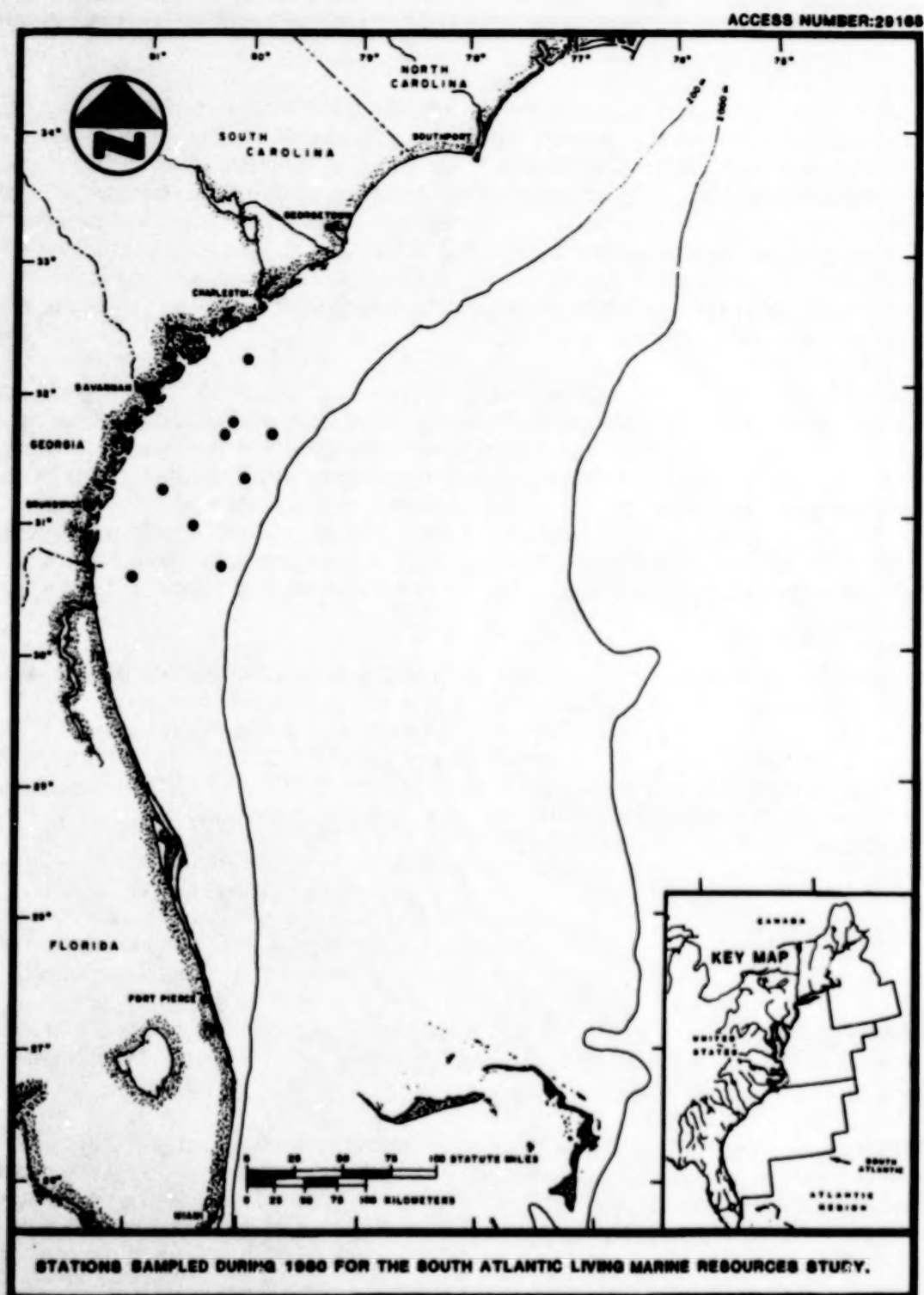
series of discontinuous relict reefs that extend from offshore North Carolina to northern Florida. Rock samples from inner and middle shelf stations were similar in composition, consisting of heavily encrusted and bioeroded fragments of sandy biomicrite. Only one sample, a quartz sandstone rock, was obtained from an outer shelf station.

A total of 1,175 invertebrate taxa were collected by dredge, trawl, suction, and grab sampling. Species richness and biomass of epibenthic organisms differed between stations and seasons, but not in a consistent pattern. At stations offshore South Carolina, Georgia, and Florida, sponges contributed the most biomass (especially at inner shelf stations, where large sponges were common) and the most frequently collected organisms in dredges and trawls were species of bryozoans, hydroids, and sponges. At stations offshore North Carolina, macroalgae, hard corals, and molluscs contributed the most biomass, and species of macroalgae, molluscs, and decapod crustaceans were the most frequently collected organisms. Species composition varied in relation to depth, with inner and outer shelf biota being the most dissimilar.

Fish abundance, biomass, and community composition varied in relation to depth, season, and time of collection (day vs. night). The biomass and abundance of commercially important species were highest at middle shelf stations. Biomass was higher during summer than winter at most stations. Night trawls collected a different and more diverse group of fishes than day trawls. Abundances of most species showed large seasonal differences, but seasonality of biomass and species composition was lowest at middle shelf stations. Benthic crustaceans (decapods, amphipods, etc.) were a major food source for most of the fish species (four from stations offshore North Carolina; seven from the remaining stations) whose gut contents were examined, but diets of the fishes showed little overlap.

STUDY PRODUCT(S): Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, and Georgia Department of Natural Resources, Coastal Resources Division. 1981. South Atlantic OCS Area Living Marine Resources Study. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Set - NTIS No. PB82160086; Executive Summary - NTIS No. PB82160094; Vol. I - NTIS No. PB82160102; Vol. II - NTIS No. PB82160110; Vol. III - NTIS No. PB82160094; Appendices - NTIS No. PB82160094. Contract No. AA551-CT9-27.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Study of the Resources from Oil Spills to Commercial Fishing (North and Mid-Atlantic OCS).

REPORT TITLE: Assessing the Impact of Oil Spills on a Commercial Fishery.

CONTRACT NUMBER(S): BLM: CT0-75; MMS: 14-12-0001-29181.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1980; 1981; 1982.

COMPLETION DATE OF REPORT: July 1982.

COST(S): FY 1980: \$590,000; FY 1981: \$186,223; FY 1982: \$177,845;
Cumulative Project Cost: \$954,068.

PROJECT MANAGER(S): C. Griscom.

AFFILIATION: University of Rhode Island.

ADDRESS: Kingston, Rhode Island 02881.

PRINCIPAL INVESTIGATOR(S)*: E. Anderson, T. Isaji, E. Lorda, M. Reed, S. Saila, M. Spaulding, C. Swanson, H. Walker.

KEY WORDS: North Atlantic; Mid-Atlantic; Georges Bank; physical oceanography; commercial fishing; assessment; modeling; ichthyoplankton; transport; spawning; oil spill; hydrodynamics.

BACKGROUND: Unique circulation patterns on the Georges Bank act to retain fish eggs and larvae within the area, assuring successful recruitment of commercially important species. This is one reason why Georges Bank sustains some of the world's most productive fisheries. Oil and gas activities on the North-Atlantic Outer Continental Shelf (OCS) pose possible threats to these fisheries. To aid environmental managers in assessing potential impacts, a sophisticated model was developed which allowed risk assessment, spill forecasting, and fishery impact assessment.

OBJECTIVES: (1) To develop a working oil spill fishery impact assessment model; (2) To identify deficiencies in model sensitivity and environmental input data; and (3) To validate the model by comparing simulated outputs with observed data.

DESCRIPTION: An oil spill fishery impact assessment model was developed and composed of integrated subroutines which simulate shelf hydrodynamics, oil spill fates, ichthyoplankton transport and fates, and fishery population dynamics. A three-dimensional hydrodynamic sub-model predicts the tidal, wind, and density forcing. Data input obtained from oceanic drifter data are estimates of monthly net transports arising from tidal, meteorological, density gradient, and pressure forcing. A fishery sub-model predicts variability in year-class strength and age structure in fish stocks using stochastic versions of a nonlinear Leslie Matrix. Validation was accomplished using available catch

data for Atlantic cod, Atlantic herring, haddock, and yellowtail flounder. Spatial and temporal spawning patterns (including egg production) were also input. An ichthyoplankton transport and fates sub-model predicts dispersion and advection of fish eggs and larvae using a random walk procedure. Ichthyoplankton are eliminated as they are impacted by surface and subsurface oil concentrations exceeding a predefined (threshold) value. Data input to the hydrodynamics and fishery sub-models are also used with the ichthyoplankton sub-model. An oil spill fates sub-model predicts spreading, drifting, evaporation, entrainment, subsurface transport, sinking, and treatment effects. A three-dimensional convective diffusion equation was used to simulate subsurface transport of dispersed oil. Output is governed by a conservation of mass concept: the sum of hydrocarbons on the water surface, in the water, and in the air at a given time must equal the total mass of oil released up to that time, minus any lost through open boundaries of the oil spill fates sub-model. Entrainment, dissolution, and breaking wave characteristics were also included. Spatial and temporal distributions of wind speed and direction, air and water temperature, and spill parameters of oil type, amount, rate, and start time were input to the oil spill fates sub-model. Interaction among the sub-models provides an oil spill impact analysis on selected fish populations. The model was tested in a deterministic hindcast mode by comparing modeled predictions with observed data from the IXTOC I oil spill. This model was subsequently updated to include probabilistic and stochastic assessments of catch losses, and effects of multiple aperiodic spills.

SIGNIFICANT CONCLUSIONS: A complex interaction exists among spill location and timing, the spatial and temporal spawning distribution of the fishes, and the hydrodynamics of the region. Uncertainty in pre-recruit mortality estimation was the most important factor affecting model estimated impacts. Accurate hydrographic data are essential for reliable simulation of oil and ichthyoplankton dispersion and advection. For the Georges Bank region, impact predictions showed distinct seasonal variability. Largest simulated impacts predicted were for spring and winter spills and for cod and haddock. These predictions suggest that exact spill timing is an important factor in evaluating potential spill impacts. Comparisons between hindcast model runs and observed data for the IXTOC I spill were generally in agreement.

STUDY RESULTS: Twenty-four simulations (eight oil spill scenarios for three fish species) were performed. One case included a 68 million gallon blowout of Stratford Norway Crude at the north site (40°37'N Lat, 68°12'W Long) during spring for Atlantic cod. Net direction of surface oil was primarily toward the northeast, reflecting the seasonally averaged wind and density induced current field. Subsurface oil concentration (50 ppb) followed the clockwise gyre known to occur over Georges Bank. A rapid time response (2 to 3 days) was observed for the transfer of oil from water surface to atmosphere or water surface to subsurface. Ichthyoplankton entrained in the gyre were affected by oil spill events within 30 to 60 days after the spill. Oil and ichthyoplankton were transported to the northeast along the northern edge of Georges Bank.

Extrapolating from the number of eggs spawned during one spawning cycle, 41.5% of the spawned cod were affected by surface or subsurface oil concentrations in excess of 50 ppb. The large impact on cod was related to their short spawning season. An expected consistency between ichthyoplankton simulations and fishery loss simulations was observed. The reduction of the initial cod (Year-0) cohort by 41.5% was input to the deterministic fishery model. After a 50-year simulation, the cumulative loss peaked at 23.9% in the seventh year.

Final mass balances of all spill fates model runs indicated that 36% of the total oil evaporated and varied only 1 or 2% depending on season. Amount entrained in the water column, 4 to 9%, was

highest in winter and smallest in summer. Mean direction of surface and subsurface trajectories shows that the qualitative behavior is a strong function of season but only weakly dependent on spill location or size. The oil spill fates hindcast predictions for IXTOC I compared well with existing data for hydrocarbon mass balance. Trajectory predictions for the surface oil agreed with observations of direction and magnitude of motion. Model predictions for subsurface oil distribution were generally in agreement with available data.

STUDY PRODUCT(S): University of Rhode Island and Applied Science Associates, Inc. 1982. Assessing the Impact of Oil Spills on a Commercial Fishery. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB83-149104. Contract No. AA851-CT0-75. 142 pp. + abstract.

Anderson, E. L. and M. L. Spaulding. 1981. Application of an oil spill fates model to environmental management in Georges Bank. *Environ. Prof.* 3:119-132.

Spaulding, M. D., E. Anderson, and K. Jayko. 1982. Hindcast of the ARGO MERCHANT spill using the URI oil spill fates model. *J. Ocean. Engr.* 9(5): 455-482.

Spaulding, M. L., S. B. Salla, E. Lorda, H. Walker, E. Anderson, and J. C. Swanson. 1983. Oil spill fishery impact assessment model: application to selected Georges Bank fish species. *Est. Coast. Shelf Sci.* 16:511-541.

Isaji, T. and M. L. Spaulding. 1984. A model of the tidally induced residual circulation in the Gulf of Mexico and Georges Bank. *J. Phys. Oceanogr.* 14(6):1119-1126.

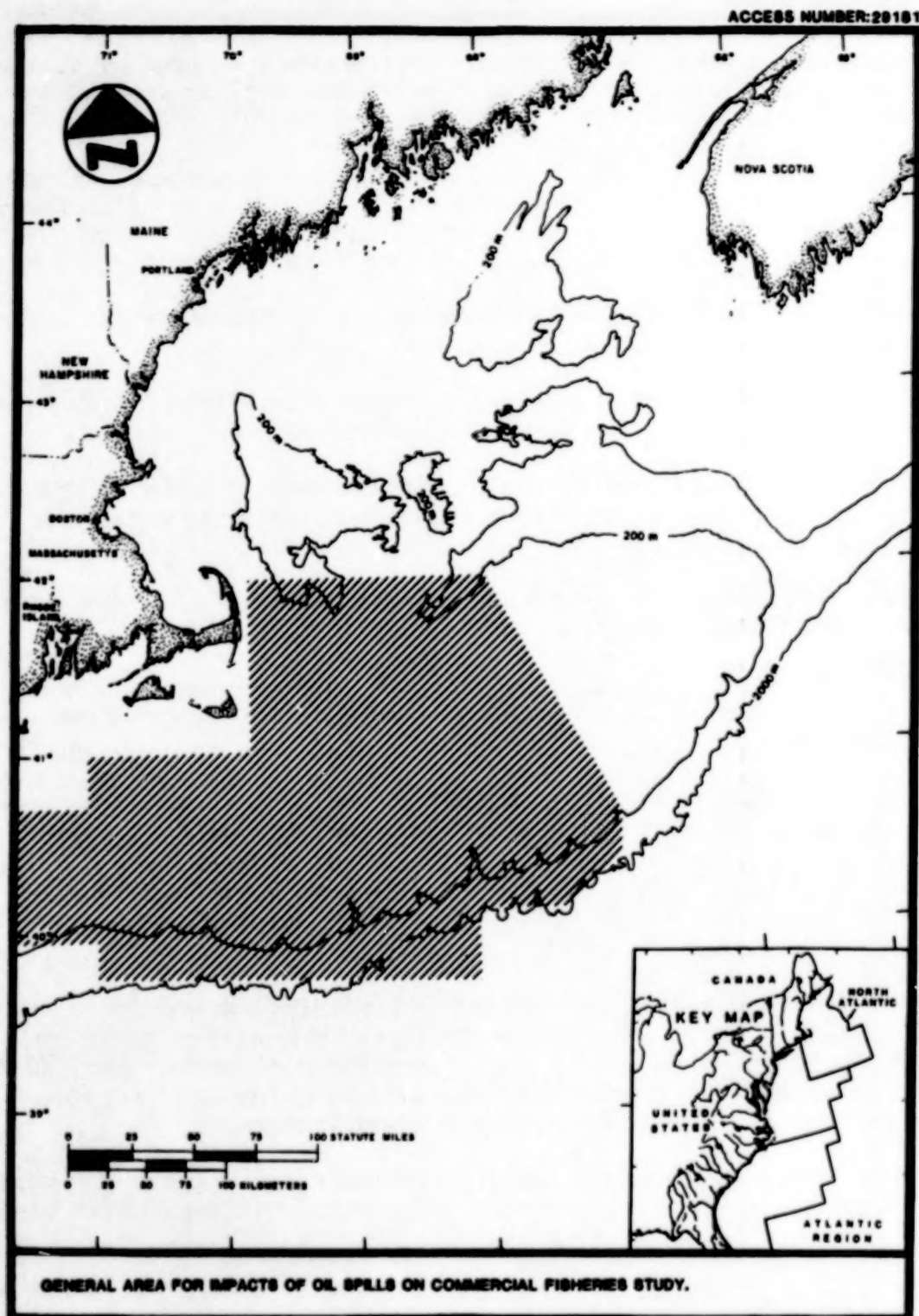
Isaji, T., M. L. Spaulding, and M. Reed. 1984. A numerical modeling characterization of the annual three dimensional circulation in the Georges Bank-Gulf of Maine region. An internal report of Applied Science Associates, Inc.

Reed, M., M. L. Spaulding, E. Lorda, H. Walker, and S. B. Salla. 1984. Oil spill fishery impact assessment modeling: The fisheries recruitment problem. *Est. Coast. Shelf Sci.* 19:591-610.

Spaulding, M. L., M. Reed, E. Anderson, T. Isaji, S. B. Salla, E. Lorda, and H. Walker. 1985. Oil spill fishery impact assessment model: sensitivity to spill location and timing. *Est. Coast. Shelf Sci.* 20:41-53.

Other publications include conference proceedings (Reed and Spaulding, 1981; Reed et al., 1982; Anderson, 1983) and submitted journal articles. Additionally, two M.S. theses (Jayko, 1981; Anderson, 1982) and one Ph.D. dissertation (Lorda, 1983) were completed at the University of Rhode Island utilizing data collected during the work effort.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic Living Marine Resources Study, Year II.

REPORT TITLE: South Atlantic OCS Area Living Marine Resources Study--Year II. Executive Summary; Vols. I through III.

CONTRACT NUMBER(S): BLM: CT1-18; MMS: 14-12-0001-29185.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1981; 1982.

COMPLETION DATE OF REPORT: December 1982.

COST(S): FY 1981: \$985,906; FY 1982: \$434,473; Cumulative Project Cost: \$1,420,379.

PROJECT MANAGER(S): V. Burrell, Jr.

AFFILIATION: Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department.

ADDRESS: Box 12559, Charleston, South Carolina 29142.

PRINCIPAL INVESTIGATOR(S)*: E. Barber, P. Fowler, P. Hinde, G. Johnson, W. Kirby-Smith, R. Matheson III, T. Mathews, G. Sedberry, J. Ustach, R. Van Dolah, E. Wenner.

KEY WORDS: South Atlantic; North Carolina; South Carolina; Georgia; Florida; biology; hard-bottom; shelf; epifauna; fish; hydrography; videotapes; photographs; seasonality.

BACKGROUND: Widespread areas of hard bottom on the continental shelf offshore the southeastern United States are important to commercial and recreational fisheries of the region, but the ecology of these areas is poorly known. The region has been opened to oil and gas exploration, and areas of prime industry interest often coincide with outcroppings of sedimentary rocks that support abundant sessile epibiota and bottom fishes. This study, which was a second-year continuation in a multi-year program, was funded to provide a better understanding of such "live-bottom" habitats so that potential impacts of oil- and gas-related activities could be assessed and minimized.

OBJECTIVES: (1) To characterize invertebrate and fish communities associated with representative live-bottom habitats on the continental shelf offshore the southeastern United States; (2) To characterize food habits of selected fish species of commercial or recreational importance; (3) To conduct a limited assessment of bottom topography and substrate type; and (4) To evaluate potential impacts of oil- and gas-related activities on live-bottom organisms.

DESCRIPTION: Three representative live-bottom stations were chosen in each of three depth ranges (inner shelf, 16 to 25 m; middle shelf, 26 to 45 m; and outer shelf, 46 to 100 m) on the continental shelf offshore North and South Carolina and Georgia. Five of the nine stations had been sampled during Year 1 (1980) of this study. All stations were sampled during winter (February-March), spring (April-May), summer (July-August), and fall (October-November) of 1981. Sampling at each station generally included: (1) profiles (10-m depth intervals) of water column temperature, salinity,

transmissivity, and dissolved oxygen, and a light penetration (Secchi depth) measurement; (2) three 20-min transect surveys using a towed television system; (3) collection of 25 color still photographs, each encompassing an area of 3.0 m²; (4) trawl sampling of fishes and other nekton using a 40/54 fly net (3 day and 3 night tows of 1 km each); (5) deployment of baited fish gears (Antillean S-traps and electric reels on rods); (6) collection of juvenile fishes using an epibenthic sled (two 5-min night tows); (7) dredge sampling of epibiota and rocks using a heavy-duty Cerame-Vivas rock dredge (two 0.1-km tows); and (8) collection of five samples of small epibiota and infauna in sediments overlying hard bottom using 0.1-m² suction (inner and middle shelf stations) or Smith-McIntyre grab (outer shelf stations) samplers.

All samples and data were processed and analyzed to produce physical and biological descriptions of the stations and to elucidate spatial and seasonal trends. Physical descriptions were based on data from television surveys. Benthic epibiota were characterized by analysis of television and still photographs and data from dredge, trawl, and suction/grab sampling. Numerical classification techniques were applied to dredge, trawl, and suction/grab data; diversity (Shannon index) and evenness (Pielou's J') values were calculated and dominance-diversity curves plotted only for the suction/grab data. Fish populations were described (biomass and abundance) on the basis of data from trawls, baited fish gears, television surveys, and epibenthic sled sampling. Stomach contents of selected fish species were analyzed to determine the composition and inter-species overlap of fish diets.

SIGNIFICANT CONCLUSIONS: Live-bottom areas were typified by expanses of sand-covered hard bottom and scattered outcrops and ledges of low to moderate relief (generally <2 m). Outcrops were most common at inner and outer shelf stations offshore North Carolina. Bottom coverage by epibiota averaged 75 to 100% for all stations. Both tropical and warm-temperate forms of invertebrates and fishes were common. Species composition of live-bottom communities varied in relation to depth and, to a lesser extent, latitude and season. Sponges accounted for most of the attached biomass (wet weight) and for the largest number of species at all stations except on the inner and middle shelves offshore North Carolina. Enhanced abundance and diversity of fishes in comparison to results reported for soft-bottom habitats reflects in part availability of numerous food organisms and shelter associated with live-bottom habitats. Offshore oil- and gas-related activities could damage live-bottom communities by smothering or burial of epibiota, but the presence of offshore structures could have favorable effects by increasing the amount of available habitat.

STUDY RESULTS: Bottom temperatures ranged seasonally from about 12 to 28°C on the inner shelf and from about 16 to 24°C on the middle and outer shelves. Salinities were generally >35 ppt except at a few inner and middle shelf stations that were affected by river runoff during spring. Dissolved oxygen levels were high (generally >4 ml l⁻¹) at all stations, depths, and seasons. Transmissivity (water clarity) values ranged from 44 to 97%, but there were no consistent spatial or seasonal patterns. Light penetration (Secchi depth) varied from 8 to 28 m, with the maximum noted in summer at most stations.

Substratum relief ranged from <0.5 to about 4 m but was generally <2 m at most stations. The incidence of rock outcrops ranged from 5 to 40% and was highest at inner and outer shelves stations offshore North Carolina; offshore South Carolina and Georgia, outcrops were more common on the middle and outer shelves than the inner shelf. All stations averaged between 75 and 100% coverage of live bottom; cover was highest at inner shelf stations offshore South Carolina and Georgia and inner and outer shelf stations offshore North Carolina. Live-bottom cover was not

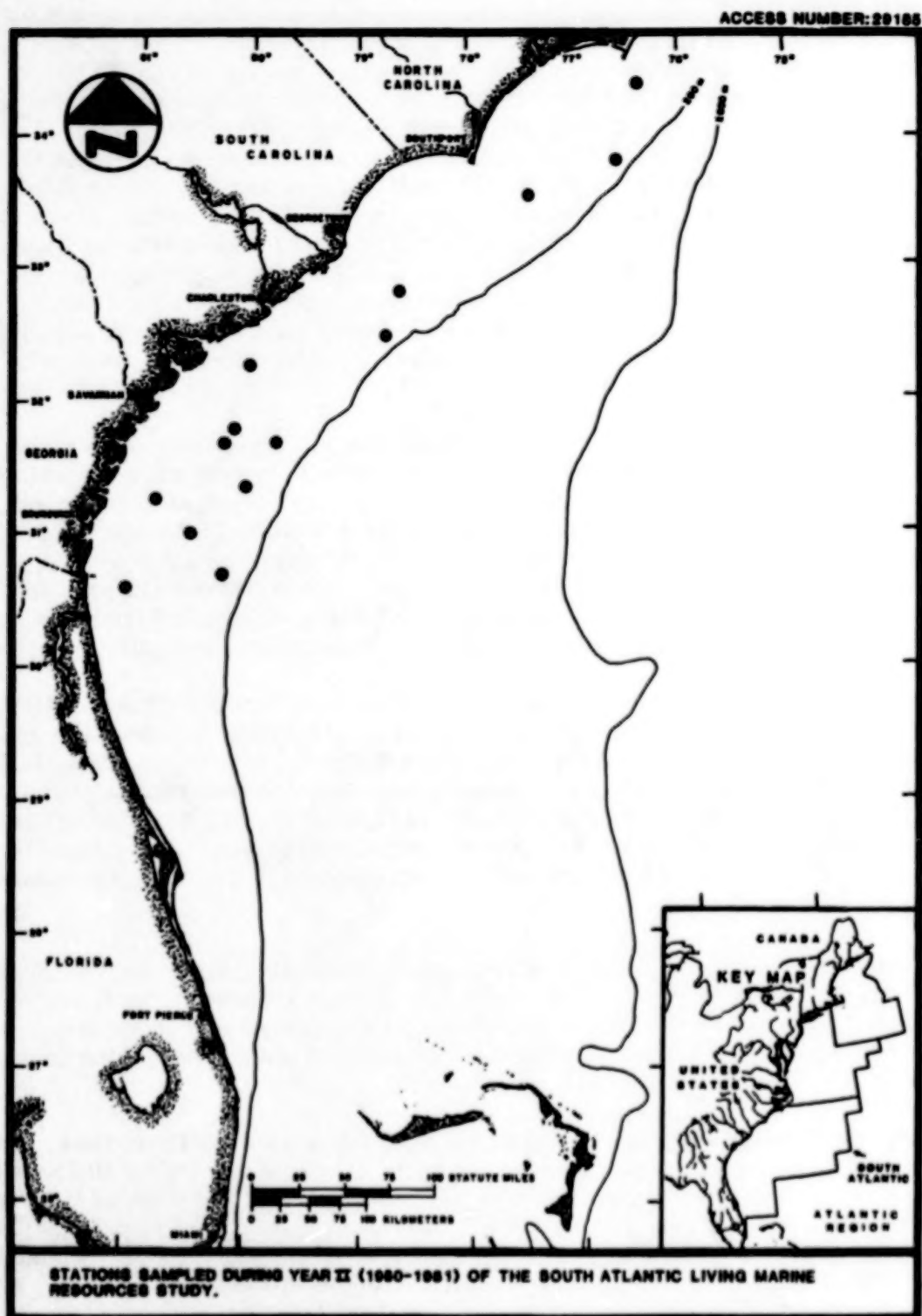
related to the incidence of outcrops because most epibiota was attached to sand-covered hard bottom.

A total of 1,307 invertebrate taxa were collected by all sampling methods. Overall species richness from dredge and trawl collections varied spatially (no consistent geographic pattern) but not seasonally. More algal species were collected during summer than during other seasons. Sponges contributed the largest number of species at inner shelf stations offshore South Carolina and Georgia and at the outer shelf North Carolina station. Biomass (wet weight) was generally higher at inner and/or middle shelf stations than on the outer shelf; sponges contributed most of the biomass at all South Carolina and Georgia stations and at the outer North Carolina station. Macroalgal abundance and biomass were highest during summer at inner shelf stations offshore South Carolina and Georgia and at the middle shelf North Carolina station. The most frequently collected organisms in dredges and trawls were species of bryozoans, cnidarians, barnacles, and echinoderms. Species composition varied in relation to depth, with inner and outer shelf biota being the most dissimilar. The epibenthic sled and suction/grab sampling collected a variety of benthic organisms that are not restricted to live bottom.

Fish abundance, biomass, and community composition varied in relation to depth, season, and time of collection (day vs. night). Overall abundance and biomass were highest and least seasonally variable at middle shelf stations. Most species showed large seasonal differences in abundance and biomass, and overall abundance and biomass were highest during fall. Diversity was highest at outer shelf stations and lowest at inner shelf stations, except during winter when some inner shelf station catches were most diverse. Night trawls collected a different and more diverse group of fishes than did day trawls. Benthic and planktonic crustaceans were important food items for bottom fishes. Low dietary overlap of the fishes studied reflects diversity of available prey items.

STUDY PRODUCT(S): Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department. 1982. South Atlantic OCS Area Living Marine Resources Study-Year II. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. Executive Summary (An Investigation of Live-Bottom Habitats in the South Atlantic Bight) - NTIS No. PB84168285; Vol. I (An Investigation of Live-Bottom Habitats off South Carolina and Georgia) - NTIS No. PB84168251; Vol. II (An Investigation of Live-Bottom Habitats off North Carolina) - NTIS No. PB84168269. Vol. III (Appendices) - NTIS No. PB84168277. Contract No. AA551-CT1-18.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic Living Marine Resources Study, 2nd Year.

REPORT TITLE: South Atlantic OCS Area Living Marine Resources Study, Phase III. Executive Summary; Vol. I, Final Report; Vol. II, Data Appendices.

CONTRACT NUMBER(S): BLM: CT1-18; MMS: 14-12-0001-29185.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1981; 1982.

COMPLETION DATE OF REPORT: August 1984 (Vol. I); October 1984 (Executive Summary, Vol. II).

COST(S): FY 1981: \$985,906; FY 1982: \$434,473; Cumulative Project Cost: \$1,420,379.

PROJECT MANAGER(S): V. Burrell, Jr., R. Van Dolah.

AFFILIATION: Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department.

ADDRESS: Box 12559, Charleston, South Carolina 29142.

PRINCIPAL INVESTIGATOR(S)*: P. Hinde, D. Knott, G. Sedberry, R. Van Dolah.

KEY WORDS: South Atlantic; South Atlantic Bight; South Carolina; Georgia; biology; hard-bottom; shelf; epifauna; fish; colonization; artificial substrates; photogrammetric technique; feeding; reefs; sediment.

BACKGROUND: Characterization of hard-bottom areas on the Outer Continental Shelf (OCS) in the South Atlantic Bight prior to oil and gas exploration activities has been a primary focus of the U.S. Department of the Interior's South Atlantic environmental studies. Initial baseline OCS studies conducted during 1981 and 1982 off South Carolina and Georgia provided descriptive biological data on fish assemblages and benthic biota. The present efforts evolved as a continuation of these studies to investigate aspects of recruitment and subsequent development of the hard-bottom communities in the South Atlantic Bight.

OBJECTIVES: (1) To determine short-term and long-term colonization patterns by invertebrates and fishes on artificial hard substrata; (2) To determine how changes in sediment depth over hard substratum influence the distribution and abundance of large sponges and corals; and (3) To describe the food habits of several fishes typically found in hard-bottom areas of the South Atlantic Bight.

DESCRIPTION: To satisfy the above objectives, this study was divided into three tasks. Task I sought to investigate aspects of short-term and long-term colonization of artificial structures by fishes and invertebrates. Short-term colonization was monitored using experimental fouling plate arrays deployed at two OCS sites (one soft bottom and one hard-bottom site) located off South Carolina in 20 m water depths. Deployed during 1983, each array consisted of 40 fouling plates arranged in horizontal and vertical series (five plates/series) on a rectangular frame (4.0 m x 2.4 m x 1.5 m) equipped with an acoustic pinger to facilitate relocation by divers. The external surfaces of

the fouling plates (20 x 25 cm) were black, textured Formica. Experimental design included five replicate plates randomly selected from each of four treatment groups (series of plates) for retrieval at 3-, 6-, 9-, and 12-month intervals. In the laboratory, plates were analyzed for percent cover, biomass, and species number of sessile invertebrates. Percent cover of sessile biota was estimated using random dot overlays covering a 225 cm² area, then plates were scraped and the biota weighed. Biomass was obtained for the following groups: Actiniaria, Algae, Ascidiacea, Cirripedia, Hydroides, Mollusca, Polychaeta, and Porifera. Motile fauna, collected by covering the plates with Plexiglas boxes prior to retrieval, were identified, weighed, and counted. Fishes were also censused during each plate collection visit. Long-term colonization patterns were studied on five artificial reefs (sunken ships) ranging in age from 3.5 to 10.0 years located off South Carolina and Georgia. Close-up photoquadrats taken along transects traversing vertical and horizontal surfaces of the sunken vessels were analyzed for epifaunal community development. Epifaunal samples (scrape and suction) collected from corresponding quadrats aided in the identification of species in the photos and provided biomass estimates. Fishes were censused by divers during each collection trip to the artificial structures. In Task II, six hard-bottom areas located at inner and middle shelf regions off Georgia and South Carolina were surveyed to determine sponge and coral distribution in relation to sediment thickness. At each study site, divers counted sponges and corals (soft and stony) occurring within quadrats placed at fixed intervals along transects traversing the hard-bottom community. Within each quadrat, sediment thickness was measured at fixed points and at the bases of attached sponges and corals. Correlation analyses were used to examine the relationship between sediment thickness and distribution of attached invertebrates. Task III involved detailed investigation of the feeding ecology of 14 commonly occurring hard-bottom fishes: black sea bass, gag, jackknife-fish, pinfish, red porgy, red snapper, sand perch, scamp, sheepshead, southern porgy, tomtate, twospot cardinalfish, vermillion snapper, and whitebone porgy. Specimens analyzed for food habits were obtained during two cruises in 1981 (one in winter, one in summer) and four cruises in 1982 (winter, spring, summer, fall) from 11 hard-bottom stations using trawls, traps, hook-and-line, and spears. Food habits and feeding behavior were determined by identifying stomach contents and comparing the composition of the prey with composition of the biota taken in bottom samples from the same habitats.

SIGNIFICANT CONCLUSIONS: Damage to hard-bottom communities from oil and gas operations would take years to recover and would significantly affect the feeding ecology of many reef fishes. If environmental risks were minimized, oil and gas structures placed on sand bottom areas would act as artificial reefs and promote the concentration of fishes and invertebrates in areas which previously had none. Sediment thickness is an important variable dictating the development of attached invertebrate communities in the South Atlantic Bight. Increased sediment loads over hard-bottom areas would inhibit colonization or recovery of the sponge and coral species studied.

STUDY RESULTS: Short-term colonization studies indicated that recruitment of sessile organisms was significantly related to seasons with respect to biomass, percent cover, and species richness. Plates colonized near hard-bottom areas supported a higher number of species than those near sand bottom areas but major differences were not observed with respect to total cover or biomass. Colonial forms such as barnacles and hydroids were the numerically dominant taxa initially colonizing the plates. Algae and ascidian cover was greater on the ventral surface of the settlement plates. Total cover, biomass, and number of species increased significantly on plates submerged for three to twelve months. Species composition changed markedly with time and differed between the two areas. After 12 months in the field, sessile communities had not attained a climax state and none of the ubiquitous sponges or corals typical of natural hard-bottom areas had

colonized the plates. Motile epifauna recruiting to the plates were dominated by amphipods. The level of recruitment was seasonally variable with peak colonization occurring in winter and spring. Periodic abundance fluctuations of a few species typified colonization patterns observed for motile epifauna. Fishes were immediately attracted to the frames near hard-bottom sites; at sand bottom sites the same fishes were attracted though it took longer. Long-term colonization studies did not reveal any consistent trends in total biomass, species composition, or percent cover of attached epifauna with age of the artificial reef. These community parameters were all significantly greater on vertical than on horizontal surfaces. Fish abundances were not significantly different among the artificial reefs and were similar to those occupying natural hard-bottom areas. Number of fish species counted among the reefs ranged from 18 to 24, with abundances ranging from 7,911 to 24,965.

Approximately 5,000 sponges and corals were counted in 597 quadrats from the six survey sites during Task II. Octocorals were more abundant than sponges at all six stations. Hard corals were uncommon at all stations. Ninety five percent of all sponges and 93% of all corals examined occurred in sediment depths <5.0 cm.

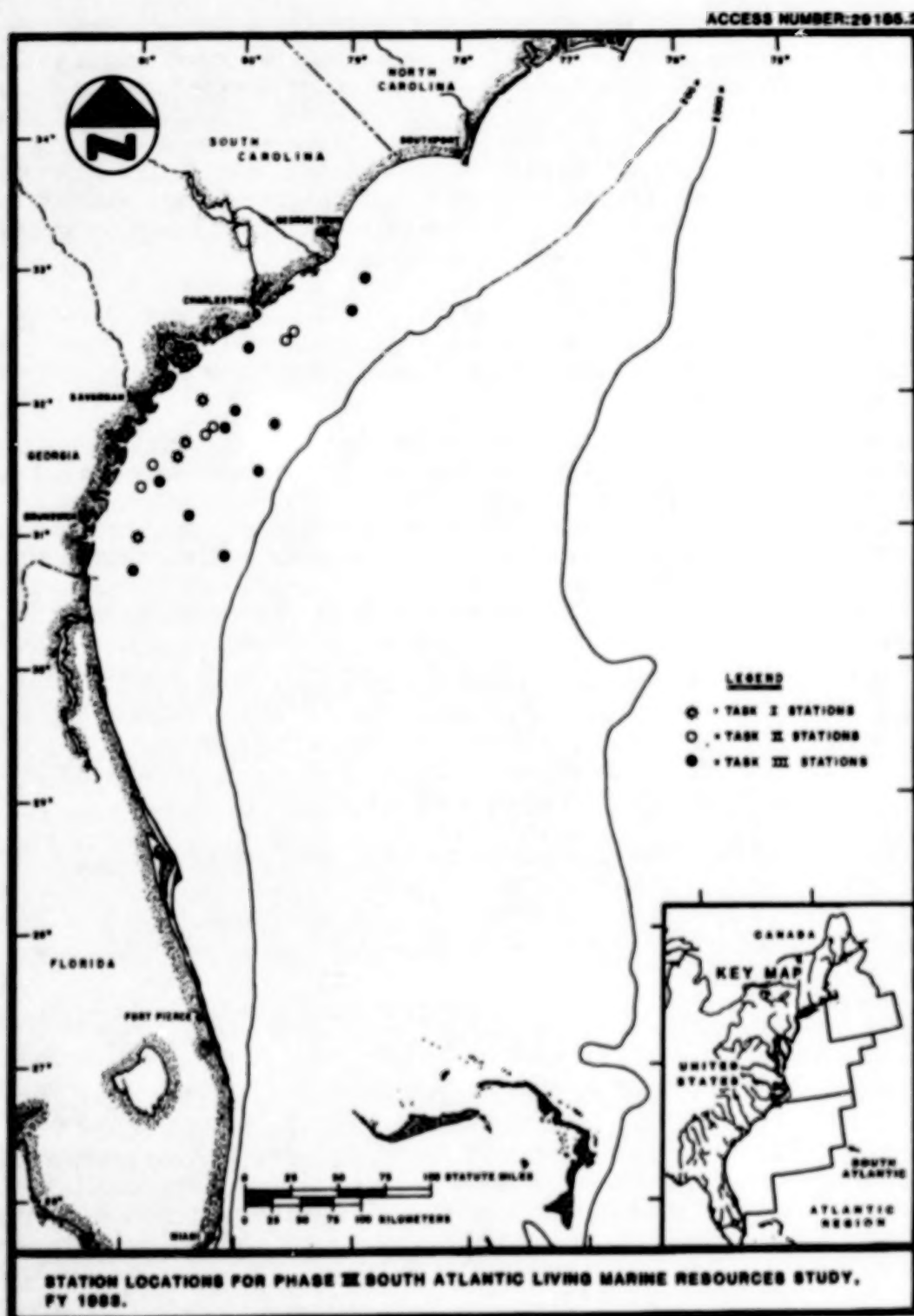
Fishes feeding near hard-bottom areas allotted their feeding activities among the various habitats. Of the species examined red porgy and small black sea bass consumed amphipods and decapods; gag, red snapper, and scamp fed primarily on other fishes; vermilion snapper and twospot cardinalfish mostly foraged on planktonic invertebrates; whitebone porgy selectively fed upon gastropods and hermit crabs; sheepshead grazed heavily on epifauna such as barnacles; tomtate, southern porgy, jackknife-fish, pinfish, and sand perch fed on infaunal invertebrates characteristic of adjacent sand bottom areas. Despite the presence of species groups exploiting similar resources, there was little overlap in diet due to spatial and temporal partitioning.

STUDY PRODUCT(S): Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, and the Georgia Department of Natural Resources, Coastal Resources Division. 1984. South Atlantic OCS Area Living Marine Resources Study, Phase III. Executive Summary. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-29185. 10 pp.

Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, and the Georgia Department of Natural Resources, Coastal Resources Division. 1984. South Atlantic OCS Area Living Marine Resources Study, Phase III. Vol. I: Final Report. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-29185. 247 pp.

Marine Resources Research Institute, South Carolina Wildlife and Marine Resources Department, and the Georgia Department of Natural Resources, Coastal Resources Division. 1984. South Atlantic OCS Area Living Marine Resources Study, Phase III. Vol. II: Data Appendices. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-29185. 82 pp.

**PI.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: North Carolina Fisheries and Environmental Data Search and Synthesis Study.

REPORT TITLE: North Carolina Fisheries and Environmental Data Search and Synthesis Study.
Executive Summary; Final Report.

CONTRACT NUMBER(S): BLM: CT1-68; MMS: 14-12-0001-29189.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): Mid-Atlantic; South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1981.

COMPLETION DATE OF REPORT: June 1983.

COST(S): FY 1981: \$169,730; Cumulative Project Cost: \$169,730.

PROJECT MANAGER(S): D. Gettleison.

AFFILIATION: Continental Shelf Associates, Inc.

ADDRESS: 759 Parkway Street, Jupiter, Florida 33477.

PRINCIPAL INVESTIGATOR(S)*: B. Balcom, N. Coulter, R. Hammer, R. Levow, R. Shaul, M. Thompson.

KEY WORDS: Mid-Atlantic; South Atlantic; North Carolina; biology; geology; physical oceanography; benthos; community; commercial fishing; recreational fishing; endangered species; shelf; literature review; historical review; synthesis; data management; abstracts; bibliography.

BACKGROUND: Significant oil and/or gas reserves may be located under portions of the North Carolina Outer Continental Shelf (OCS). Several tracts have been leased off the North Carolina coast and additional areas have been nominated for further lease sales. The U.S. Department of Interior, Minerals Management Service (MMS) has responsibility for leasing Federal OCS lands and conducting studies in lease sale areas to ascertain and minimize environmental impacts on human, marine, and coastal environments that may be affected by oil and gas activities. This study updates all useful information on living marine resources and habitats of the North Carolina OCS for use by the MMS and others to support management decisions concerning oil and gas activities.

OBJECTIVES: (1) To collect, annotate, and synthesize all useful information on living marine resources and habitats of the North Carolina OCS.

DESCRIPTION: The North Carolina OCS is defined as from the shoreline to a depth of 200 m (656 ft), and from a northern boundary of 36.5°N Lat to a southern boundary of 33.0°N Lat. The study was divided into four separate but related phases: (1) identification and selective collection of published and unpublished information; (2) review and annotation of the information; (3) development of a computer program that accesses, cross-references, and stores the database; and (4) interpretation and synthesis of information in a technical report with separate visuals (maps) and an executive summary. Over 1,450 published and unpublished data sources were reviewed. The synthesis report contains summaries for the following topic areas: geology, oceanography, biological communities, commercial and sport fisheries, endangered and threatened species, and sensitive

biological areas and unique habitats. Data gaps were identified, implications to OCS development were discussed, and suggestions for additional research were provided.

SIGNIFICANT CONCLUSIONS: The North Carolina OCS is a transition zone between the South and Middle Atlantic Bight. The climate, proximity, and behavior of the Gulf Stream, and presence of cusped projecting shoals and capes influence unique oceanographic and biological features. Extensive hard-bottom and live-bottom areas were present within Onslow Bay and along the North Carolina continental shelf edge. Upwelling along the shelf edge and intrusion of nutrient rich eddies into mid-shelf and inner-shelf waters occur frequently. The upwelling, eddy formation-intrusion phenomenon is not well studied and makes risk assessment for OCS development difficult.

STUDY RESULTS: The continental margin off North Carolina typifies Atlantic-type continental margins, in that it has had a relatively long period of tectonic stability. There are cusped projections and shoals off the capes, large sand ridges that generally align at right angles to the shoreline, and terrace-like features along the shelf edge. Extensive hard-bottom and live-bottom exist within Onslow Bay and in other areas along the North Carolina continental shelf edge. These hard-bottom areas are of several geologic origins and types. Relic and calcareous sediments dominate the Carolina Shelf indicating low terrigenous deposition. Shelf edge and slope sediment slumping is the primary geological hazard to OCS development. Incidence of faulting and sediment slumping on the shelf is low.

Study area coastal climate is described as temperate-rainy. Five processes control seasonal current patterns off North Carolina: (1) winter wind-driven, near-coast advection from north of Cape Hatteras; (2) persistent intrusions of near-surface Gulf Stream meanders and eddies; (3) late summer, wind-driven, subsurface intrusions of Gulf Stream waters; (4) cooling of shelf waters by atmospheric cold fronts and subsequent down slope cascading of water; and (5) river run-off. Cusped embayments, capes, and cape shoals affect coastal circulation patterns by forming barriers to alongshore currents and steering upwelled waters. Gulf Stream meanders, at times, form an upwelling ridge bringing nutrient rich waters to the Carolina Shelf. This event results in a short period phytoplankton bloom followed by increased abundance of zooplankton and eventually fishes.

Overall phytoplankton abundance and species diversity tend to decrease with distance from shore. Phytoplankton communities have a regional demarcation in the Cape Hatteras vicinity with neritic and pelagic species south of the cape exhibiting subtropical and tropical affinities, and species north of the cape exhibiting temperate or boreal affinities. Generally, total zooplankton concentrations tend to decrease with distance offshore. A total of 67 fish families have been identified from surface ichthyoplankton samples off North Carolina and another 60 fish families from midwater samples. Three distribution patterns occur, characterized by families spawning in the area, including the shelf, shelf/slope, and slope patterns. Benthic organisms also have three distribution patterns: along the inner shelf; the Carolinian Province south and the Virginian Province north of Cape Hatteras; and the Tropical or Caribbean Province on the outer and upper slope associated with the Gulf Stream. Seasonal fluctuations in province boundaries occur. Algal flora from coastal North Carolina are represented by 289 taxa. This diversity is due to the variety of available habitats and seasonally variable environment allowing growth of both temperate and subtropical species. Meiobenthic faunal distribution patterns are highly correlated with sediment composition and bottom water temperature. Density values are highest in the inner-shelf and mid-shelf depth ranges and lowest in depths beyond 100 m (328 ft). Live-bottom sessile invertebrate communities are of two types: (1) exposed

eroded carbonate rock outcrops within and near Oslow Bay encrusted with coral and other associated epifauna; and (2) lithothamnion reef assemblages occurring along the shelf edge.

Fishes comprise the most abundant portion of the nektonic community off North Carolina with temperate to subtropical species found nearshore and subtropical to tropical species offshore. During 1981, a total of 388,552,891 lb of finfish were landed in North Carolina, valued at \$36,280,328. This catch was represented by 55 finfish species with Atlantic croaker, Atlantic menhaden, flounders, and grey seatrout leading in terms of value. In 1981, the total shellfish harvest was 43,452,992 lb, valued at \$21,239,682. Shrimps, oysters, calico scallop, and bay scallop comprised 99% of the catch. Five species of marine turtles, 8 species of fishes, and 27 species of marine mammals that are protected by the Endangered Species Act of 1973 exist in or migrate through North Carolina OCS waters.

Four types of sensitive biological areas and unique habitats are recognized on the Carolina Shelf: (1) inner-shelf, live-bottom areas; (2) mid-shelf, live-bottom areas; (3) shelf-edge, live-bottom areas; and (4) numerous shipwrecks. Six major areas have been identified where additional studies are needed: (1) mapping and description of hard-bottom and live-bottom areas; (2) coupling of shelf upwelling events with bioproductivity; (3) review of existing data for relationships of upwelling data and fishery data; (4) fates and effects of continental and OCS substances discharged into the marine environment; (5) re-evaluation of OCS risk analyses models; and (6) multidisciplinary monitoring programs to investigate potential effects of OCS activities on endangered species and unique habitats in the study area.

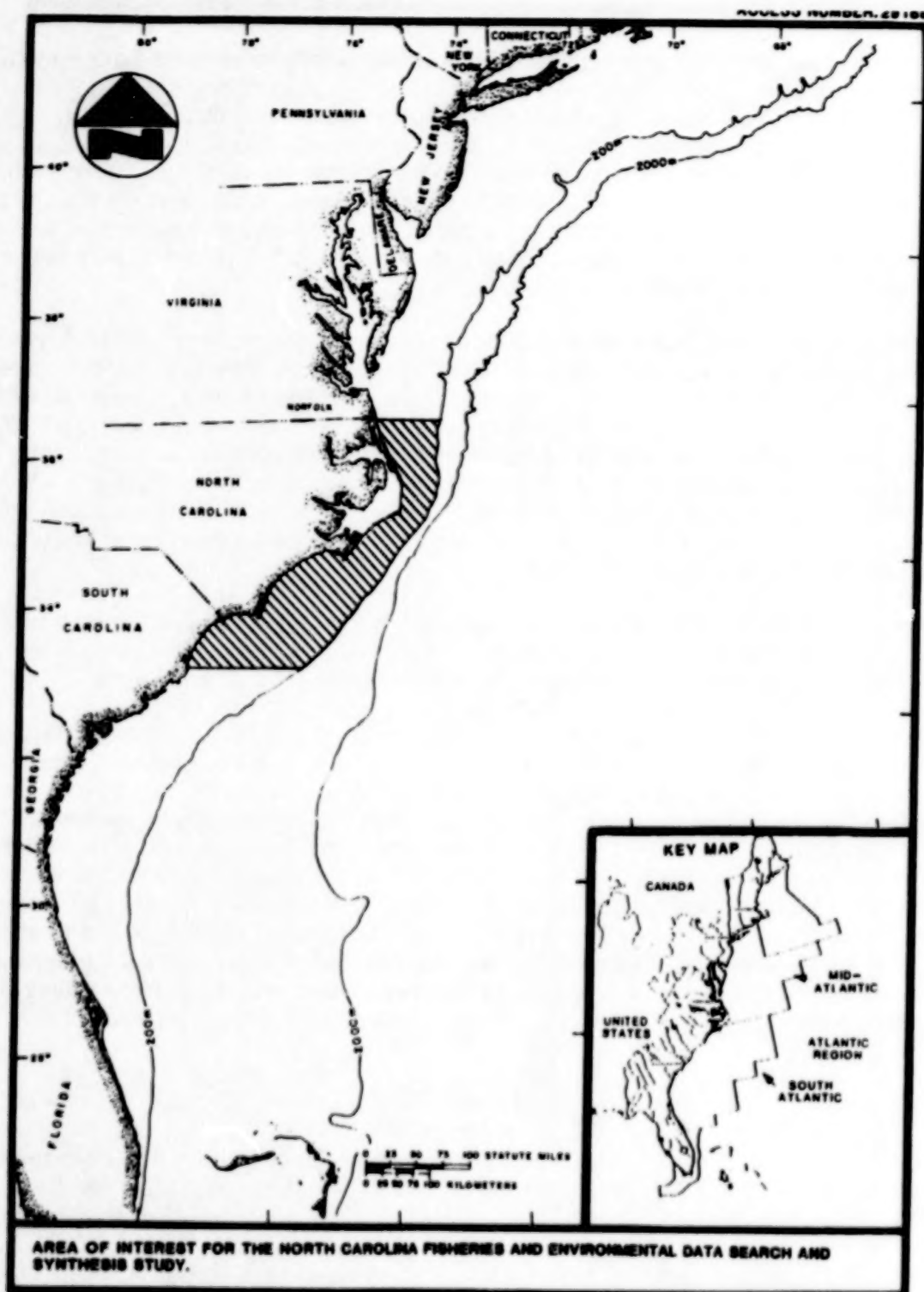
STUDY PRODUCT(S): Continental Shelf Associates, Inc. 1983. North Carolina Fisheries and Environmental Data Search and Synthesis Study. Executive Summary. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84141357. Contract No. 14-12-0001-29189. 18 pp.

Continental Shelf Associates, Inc. 1983. North Carolina Fisheries and Environmental Data Search and Synthesis Study. Final Report. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84141365. Contract No. 14-12-0001-29189. 363 pp.

Other study products include:

Abstracts of pertinent literature, typewritten and on magnetic tape. Map series consisting of five maps (scale 1:80,000) of biological and geological features. Data management computer program with documentation.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Analysis of Historical Benthic Infaunal Samples from Georges Bank.

REPORT TITLE: Georges Bank Benthic Infauna Historical Study.

CONTRACT NUMBER(S): BLM: CT1-69; MMS: 14-12-0001-29190.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1981.

COMPLETION DATE OF REPORT: March 1983.

COST(S): FY 1981: \$100,706; Cumulative Project Cost: \$100,706.

PROJECT MANAGER(S): A. Michael.

AFFILIATION: Taxon, Inc.

ADDRESS: 50 Grove Street, Salem, Massachusetts 10970.

PRINCIPAL INVESTIGATOR(S)*: C. Long, R. McGrath, A. Michael.

KEY WORDS: North Atlantic; Georges Bank; Gulf of Maine; biology; infauna; benthos; seasonality; benchmark; community; historical review.

BACKGROUND: The New England Outer Continental Shelf (OCS) Environmental Benchmark Program was initiated by the Bureau of Land Management in 1977. This was an extensive program in which 42 stations near Georges Bank were sampled quarterly. This program ended in May 1978 following review by the scientific community of benchmark studies. Only portions of the completed data sets were included in the Draft Final Report released in 1978. In 1980, when the Biological Task Force for OCS Lease Sale 42 established the Georges Bank Monitoring Program, there was support for completing the analysis of the 1977 data base. Because of the elapsed time and differences in taxonomists, only the major community parameters and dominant species were analyzed.

OBJECTIVES: (1) To complete the taxonomic identification of infaunal samples taken during Cruises III and IV of the Benchmark Program; (2) To analyze data from 11 of the Benchmark Program's 42 infaunal stations over a four-season cycle; and (3) To produce information on seasonal variation and to provide a longer term base for comparison of the new data being generated in the 1980 Monitoring Program.

DESCRIPTION: All samples collected with a 0.1-m² VanVeen grab from Cruises III and IV of the New England OCS Benchmark Program were identified. Samples had been collected quarterly, sieved

using a 0.5-mm sieve, and stored in muslin bags placed in 30-gal drums of 10% buffered formalin. Wet weight biomass of major groups (e.g., polychaetes, amphipods, molluscs) was determined after species material was blotted with a paper towel. Faunal data were entered into the Woods Hole Oceanographic Institution VAX/11-780 computer and analyzed using a suite of programs maintained specifically for benthic faunal data. These were PRARE I (diversity calculations and data listing), PERSORT (abundance rankings), and SPSTCL (classification analysis). Diversities were calculated using the Shannon-Wiener formula. Only species which occurred in approximately 30% or more of the samples were included in the analyses. Data were transformed ($\log X+1$) before analysis. Normal classification was based on the Bray-Curtis similarity measure and either group average or flexible sorting was used to cluster entities.

SIGNIFICANT CONCLUSIONS: Analysis of the benthic data collected in 1977 during the New England OCS Environmental Benchmark Program revealed several consistent trends. In general, the numbers of species and individuals increased with depth. Lowest numbers of species (10) and lowest mean densities ($1,000 \text{ m}^{-2}$) were found on the bank top, while at deeper sites in the Gulf of Maine the highest numbers of species (92) and highest densities ($40,000 \text{ m}^{-2}$) were noted. Seasonality within the benthic communities, evident in all but the deepest stations samples, was typified by increases during the spring-summer period. The lowest diversity measurements were noted for Georges Bank, while deeper stations were typically characterized as having higher diversity. Comparisons between replicate samples taken at select sites indicated low variability between replicates. When the fact is considered in conjunction with the high level of similarity and persistence within benthic communities of Georges Bank, the use of the benthos as a monitoring tool has considerable merit.

STUDY RESULTS: Approximately 700 taxonomic categories were identified. Polychaetes were numerically dominant in a majority of samples and represented the greatest proportion of species. The next most abundant and diverse group was amphipods, followed by molluscs and then echinoderms. Thirteen polychaete families containing the dominant polychaete species on Georges Bank were discussed individually. Taxonomic problems were enumerated in relation to other studies and the specific solution employed in resolving each difficulty was given.

The number of species found in any one replicate sample ranged from a low of 10 at the top of the bank to a high of 92 in the Gulf of Maine. Numbers of species present increased during the spring-summer period in all but three of the deeper stations. Mean densities of all species ranged from $1,000 \text{ individuals m}^{-2}$ in winter at the top of the bank to over $40,000 \text{ individuals m}^{-2}$ at one station in the Gulf of Maine. Numbers of individuals present increased with depth and in an east-to-west gradient across the bank. Seasonal trends in species densities occurred at the shallower stations.

Biomass measurements showed greater variability between analysts than did other biological parameters (the author suggests using caution when evaluating the results). Values ranged from 7.81 g m^{-2} at the shallowest station to 26.47 g m^{-2} at one station on the east side of the bank near the 100-m contour. Polychaetes comprised 88% of the total biomass measured.

Typically, 6 to 10 species represented more than 90% of the individuals at any given station. Six species occurred in 50% or more of all samples: the polychaetes Aricidea catherinae, Exogone hebes, E. brevicornis, and Notomastus latericeus, and the amphipods Ampelisca agassizi and

Unciola irrorata. Ampelisca agassizi was perhaps the most characteristic species of the southern flank of Georges Bank occurring in densities of over 1,000 individuals m^{-2} at seven stations.

The two shallow stations located on Georges Bank had the lowest Shannon-Wiener diversity. Higher values were typical of deeper stations. Variation in Shannon-Wiener diversity between cruises was partially attributed to taxonomic variance.

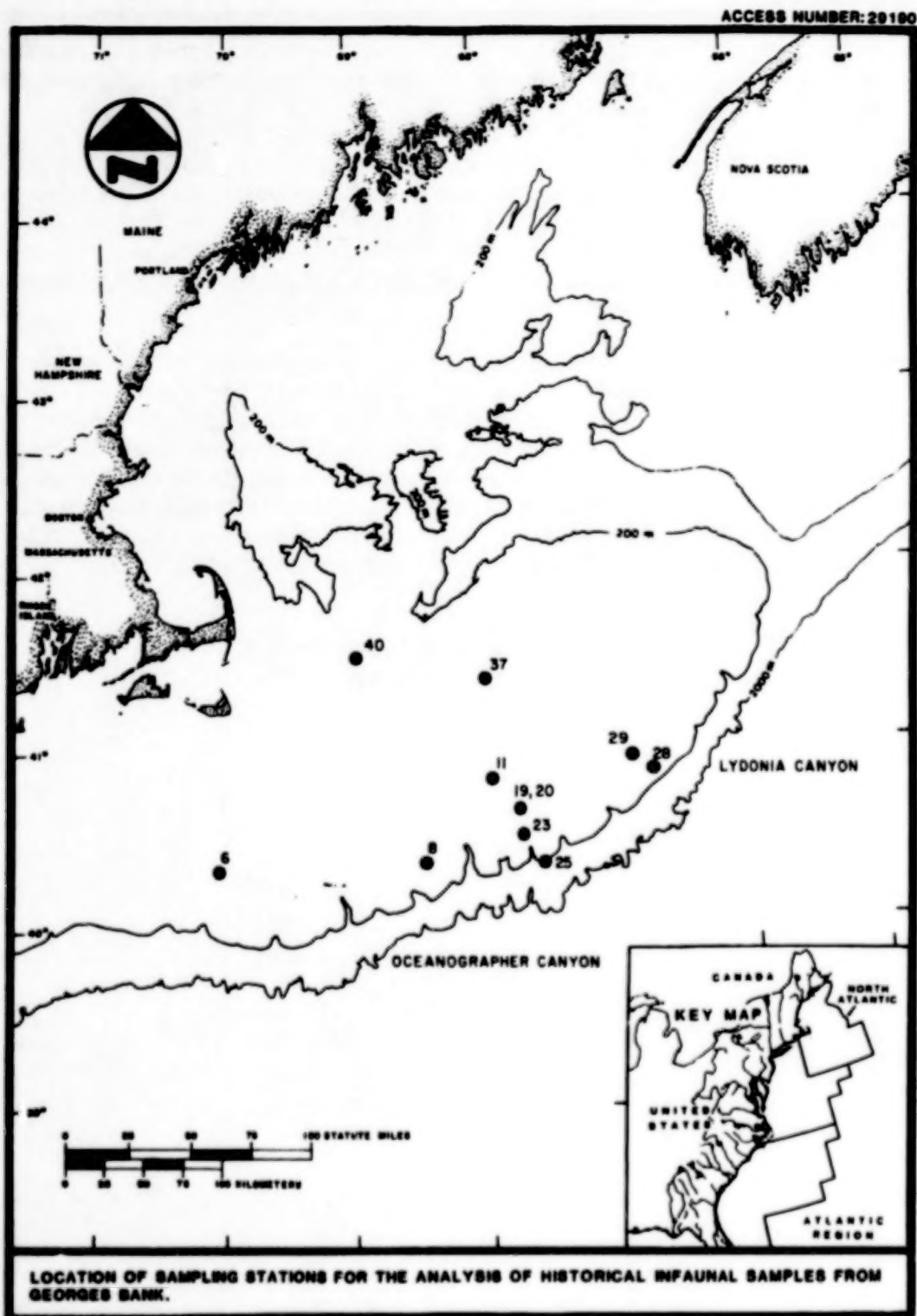
A high degree of persistence in the fauna present at most stations was reported. Only the most shallow station located on top of the bank had a high level of variability in both the fauna and the sediments sampled.

Intra-sample variance was relatively low even though in some cases replicates were spread over a circle with a radius of 500 to 800 m.

The benthic data gathered in the 1977 Benchmark Program and analyzed during this study indicated that the prospects for using the benthos as a monitoring tool on Georges Bank were good for the following reasons: (1) there are large areas on Georges Bank inhabited by the same or similar benthic communities; (2) replicate sampling within those areas showed low variability, thus enhancing the possibility of detecting statistically significant changes; (3) the persistence of these communities is high. Repeated visits to the same general locality indicated a similar fauna; and (4) the possibility of finding suitable control sites for experimental monitoring stations on the southern flank of the bank is good. Faunal composition is sufficiently similar to provide adequate control sites.

STUDY PRODUCT(S): Michael, A. D., C. D. Long, D. Mauer, and R. A. McGrath. 1983. Georges Bank Benthic Infauna Historical Study. A final report by Taxon, Inc. for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB83-252114. Contract No. 14-12-0001-29190. 171 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



III PROTECTED SPECIES

The objectives of the protected species studies are (1) to obtain data pertaining to the distribution and interrelationships of species listed under the Endangered Species Act or given protection under the Marine Mammal Protection Act and (2) to determine the potential effects of Outer Continental Shelf oil and gas operations (toxic effects, acoustic/visual disturbances, degradation of key habitat) on these species.

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STUDY TITLE: Characterization of Marine Mammals and Turtles in the Mid- and North Atlantic OCS.

REPORT TITLE: A Characterization of Marine Mammals and Turtles in the Mid- and North Atlantic Areas of the U.S. Outer Continental Shelf.

CONTRACT NUMBER(S): BLM: CT8-48; MMS: 14-12-0001-29163.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978; 1979; 1980; 1981.

COMPLETION DATE OF REPORT: December 1982.

COST(S): FY 1978: \$1,454,791; FY 1979: \$504,131; FY 1980: \$803,959; FY 1981: \$941,986;
Cumulative Project Cost: \$3,704,867.

PROJECT MANAGER(S): R. Edel.

AFFILIATION: University of Rhode Island.

ADDRESS: Kingston, Rhode Island 02881.

PRINCIPAL INVESTIGATOR(S)*: G. Carter, R. Edel, J. Gilbert, J. Hain, M. Hyman, S. Katona, C. Mayo, G. Scott, C. Shoop, W. Steiner, M. Tyrell, H. Winn.

KEY WORDS: North Atlantic; Mid-Atlantic; endangered species; marine mammals; turtles; benchmark; behavior; distribution; abundance; seasonality; feeding; migration; respiration.

BACKGROUND: The Cetacean and Turtle Assessment Program (CETAP) was initiated in June of 1978 to characterize marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. Outer Continental Shelf (OCS). This study was to present the cumulative results of CETAP for use in decisionmaking relative to oil and gas exploration and development in these planning areas.

OBJECTIVES: (1) To determine which species of marine mammals and turtles inhabit and/or migrate through the study area; (2) To identify, delineate, and describe areas of importance (feeding, breeding, calving, etc.) to marine mammals and marine turtles in the study area; (3) To determine the temporal and spatial distribution of marine mammals and turtles in the study area; (4) To estimate the size and extent of marine mammal and turtle populations in the study area; and (5) To emphasize the above items (1 to 4) for those species classified as threatened or endangered.

DESCRIPTION: The study area was defined as the waters overlying the U.S. OCS between Cape Hatteras, North Carolina and Nova Scotia, Canada, from the coastline offshore to an established line parallel to and 5 NM seaward of the 1,000-fth (1,830-m) isobath. No bays or sounds were included. From November 1978 until the end of 1980 data were collected primarily by: (1) aerial overflight;

(2) ships-of-opportunity; (3) aircraft-of-opportunity; (4) endangered species surveys; and (5) opportunistic data contributed by a number of sources. In 1981, the ships-of-opportunity program was dropped and sampling was primarily restricted to lease areas and areas where endangered species were known to be abundant. Two additional areas over the continental rise and slope were added to the study area in 1981 and a replicate sampling system was initiated to gauge the variability present in abundance estimates based on aerial survey data. Cumulative and seasonal plots of sightings were computer generated. Abundance estimates were based on an individuals-per-unit effort measure analogous to the catch-per-unit effort indices employed in fisheries science. Statistical methods for estimating population densities varied slightly with each year's annual report (1979, 1980). The technique used in the Final Report was from the Burnham et al. article, published in 1980, entitled "Estimation of density from line transect sampling of biological populations." The average "pod" size was estimated based on the average number of animals seen per sighting over the entire three-year study period. Average regional/seasonal densities were calculated as the area-weighted mean of all individual sample densities in that region and season.

In addition to the regular mission and objectives of this project, two cruises were dedicated to gathering respiration and dive-time data on endangered species in the Cape Cod area. These data were presented as a special topic in the Final Report.

SIGNIFICANT CONCLUSIONS: As a result of the CETAP field survey effort conducted over a 39-month period from mid-1978 to late 1981, a total of 170,012 cetaceans were sighted representing 26 species or species groups. Of the 14 common cetacean species noted, 6 were characteristic of shallow (<200 m) water and included the right whale, humpback whale, fin whale, whitesided dolphin, and harbor porpoise. The remaining eight cetacean species occurred along the shelf edge and beyond (≥ 200 m) and included the sei whale, sperm whale, Atlantic bottlenose dolphin, pilot whale, saddleback dolphin, and other dolphin species. Common sightings of several of the cetacean species occurred during winter associated with migratory activities.

Four species of sea turtles were identified as a result of 2,820 sightings of 3,180 individuals. These species, in descending order of occurrence, included the leatherback turtle, loggerhead turtle, green turtle, and Kemp's ridley turtle.

STUDY RESULTS: During the 39 months of CETAP field studies, 26 distinct species or species groupings of cetaceans and 4 species of marine turtles were sighted in or near the study area. Cetacean sightings consisted of 11,156 reports involving 170,012 individuals. Of the large whales, the fin whale (*Balaenoptera physalus*) and humpback whale (*Megaptera novaeangliae*) were the most common. Of the small whales, the bottlenosed dolphin (*Tursiops truncatus*), harbor porpoise (*Phocoena phocoena*), whitesided dolphin (*Lagenorhynchus acutus*), pilot whale (*Globicephala* spp.), grampus (*Grampus griseus*), and the saddleback dolphin (*Delphinus delphis*) were the most common. Large whales accounted for 998 of the sightings (1,743 individuals), while small whales showed 1,520 sightings (48,180 individuals).

CETAP presented important new findings for the behavior and distribution patterns of the right whale (*Eubalaena glacialis*) and the sei whale (*Balaenoptera borealis*), both endangered species. The program also gave unique and sometimes the only live sighting data on some of the rare species of beaked whales (i.e., *Ziphius cavirostris* and *Mesoplodon* spp.).

CETAP reported 2,820 sightings containing 3,180 individuals of four species of sea turtles. Sea turtle species sighted were leatherback turtle (Dermochelys coriacea), loggerhead turtle (Caretta caretta), green turtle (Chelonia mydas), and Kemp's ridley turtle (Lepidochelys kemp). Leatherback turtles were observed widely throughout the study area. This endangered species regularly visited the Gulf of Maine, although most sightings were south of New England. The loggerhead turtle, which is considered a threatened species, was observed on 2,594 occasions with a total of 2,926 individuals seen. This species rarely ventured into the Gulf of Maine. The Florida population of green turtle is considered endangered, while other populations are classified as threatened. This species was observed only seven times during the entire three-year field effort of CETAP. Kemp's ridley turtle, also considered an endangered species, was sighted only six times during the CETAP program.

For the 14 common species of cetaceans found in the study area, two general distribution patterns were described. Those that were included in the on-shelf group (E. glacialis, M. novaeangliae, B. physalus, B. acutorostrata, Lagenorhynchus acutus, and P. phocoena) occurred in depths less than 200 m, and the shelf-edge group (B. borealis, Physeter catodon, T. truncatus, Globicephala spp., Delphinus delphis, G. griseus, Stenella spp., and S. coeruleoalba) occurred along the shelf edge in depths greater than 200 m.

CETAP data revealed two important items with respect to migration routes within the study area: (1) many cetacean species are common in the study area during winter; and (2) many species, particularly the toothed whales (Odontocetes), are sighted regularly over the continental slope, rise, and deep ocean.

CETAP data indicated that many of the species observed spend only a portion of their life history in the study area. Migration routes are largely undescribed. Any species present in the study area is likely to be feeding both at the surface and underwater. Certain regions of the study area are particularly important as feeding grounds. These include the Great South Channel, Jeffreys Ledge Corridor, the region east-southeast of Montauk Point, and certain portions of Georges Bank.

Calves and juveniles of most species were observed in the study area. None of the CETAP data indicated any specific nursery grounds or areas preferred by mother-calf pairs.

STUDY PRODUCT(S): Winn, H. E. 1982. A Characterization of Marine Mammals and Turtles in the Mid- and North Atlantic Areas of the U.S. Outer Continental Shelf. A final report by the University of Rhode Island for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB81-243289. Contract No. AA551-CT8-48. 500 pp.

*Pl.'s affiliation may be different than that listed for Project Manager(s).



STUDY TITLE: Study of the Effects of Oil on Marine Mammals.

REPORT TITLE: Expanded Studies of the Effects of Oil on Cetaceans. Cutaneous Response to Plastic and Metallic Implants of Potential Use for Marking Cetaceans.

CONTRACT NUMBER(S): BLM: CT9-29; MMS: 14-12-0001-29169.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): All.

FISCAL YEAR(S) OF PROJECT FUNDING: 1979; 1981; 1982; 1983; 1984.

COMPLETION DATE OF REPORT: February 1985.

COST(S): FY 1979: \$926,291; FY 1981: \$111,816; FY 1982: \$500,000; FY 1983: \$446,798; FY 1984: \$33,552; CUMULATIVE PROJECT COST: \$2,018,457.

PROJECT MANAGER(S): D. St. Aubin.

AFFILIATION: University of Guelph.

ADDRESS: Ontario Veterinary College, Guelph, Ontario N1G 2W1 Canada.

PRINCIPAL INVESTIGATOR(S)*: R. Alas, K. Baker, J. Geraci, B. Hicks, C. Kasserra, G. Smith, T. Smith, D. St. Aubin, J. Umpleby.

KEY WORDS: North Atlantic; Mid-Atlantic; South Atlantic; Eastern Gulf; Central Gulf; Western Gulf; Southern California; Central and Northern California; Gulf of Alaska; Kodiak; Cook Inlet; Shumagin; North Aleutian Basin; St. George Basin; St. Matthew Hall; Navarin Basin; Norton Basin; Hope Basin; Barrow Arch; Diapir Field; fates and effects; marine mammals; hydrocarbons; exposure; bioaccumulation; behavior; histopathology; immunology; biochemistry; whales; dolphins; gas chromatography; tissue.

BACKGROUND: Because of the concern about potential environmental consequences of offshore oil spills, the U.S. Department of the Interior sponsored studies to investigate proximate and ultimate effects of direct contact with petroleum compounds on marine mammals.

OBJECTIVES: (1) To determine detection and avoidance of surface oil by the bottlenose dolphin; (2) To assess the effects of oil and gasoline on marine mammal skin; (3) To examine bioaccumulation of petroleum residues in marine mammal tissues; (4) To determine the effects of oil on baleen fouling in baleen whales; and (5) To characterize the cutaneous response in bottlenose dolphins to materials of potential value in cetacean marking programs.

DESCRIPTION: Oil effects on cetaceans were assessed through behavioral, histological, immunological, and biochemical investigations. Behavioral reaction to surface oil films under different light conditions was studied in a pen using three bottlenose dolphins. Slicks 1 cm thick were produced using clear or colored mineral oil and refined motor oil. Subjects were observed during three or four 45-min sessions for each oil treatment and for control periods. For night observations, a canopy excluding 92% of the incident moon and star light was placed over the pen. Video and audio recordings were made during each session.

Study of gasoline effects on cetacean epidermal cell growth and lipid characteristics was made in a series of experiments. Cell proliferation and turnover were investigated by applying control and gasoline filled contact dishes on the epidermis of bottlenose dolphin from Florida and Hawaii. Exposed tissue samples were incubated in labeled thymidine then subjected to autoradiography to estimate the extent of DNA replication during the exposure period. To describe epidermal lipid droplet distribution, bottlenose and common dolphin biopsies were taken with a 6-mm punch, fixed, mounted, and examined using light and electron microscopes. Random photomicrographs were taken to analyze lipid droplets. Lipids were characterized from additional epidermal biopsies. Samples were stored on dry ice until analyses could be performed. Prepared samples were analyzed for fatty acids, triglycerides, and phospholipids using silica-gel thin layer and gas chromatography. Antimicrobial properties of cetacean epidermal lipids were examined using four common marine pathogens and skin samples from bottlenose dolphin and beluga, fin, and sperm whales. Skin lipids were extracted and separated using column chromatography. Samples were inoculated with the microbes and placed in blood agar culture dishes. Effects of gasoline on skin lipids were determined in vivo using surface contact dishes. Frozen biopsies of bottlenose dolphin were subject to previously described extraction and separation techniques. In vitro effects of gasoline exposure were also examined using skin samples obtained from a stranded juvenile bottlenose dolphin. Skin response to allergens was investigated. Three bottlenose dolphin, four beluga whale, and four harp seal were sensitized and given intradermal injections of various allergens. Histological preparations of skin samples from five fin and five sei whales were examined for presence of antibody producing Langerhans cells.

Naphthalene residues were used as the accumulated compound to assess petroleum derivative bioaccumulation in 19 marine mammal species. Blubber, heart, kidney, liver, lung, mammary, and muscle tissues were analyzed with spectrophotometry and gas chromatography.

Fouling by oil was assessed using baleen samples from fin, humpback, and sei whales. Samples mounted on wooden frames were placed so that the medial surface was perpendicular to water flow in an elliptical circulating chamber. Samples were fouled with three types of oil, and resistance to flow was estimated.

Experiments assessing the cutaneous response of bottlenose dolphins to tagging materials and procedures were conducted and included in a separate report. Epidermal wound healing was examined by taking biopsies of incisions at 2, 6, and 12 h and 1, 2, 3, 7, and 10 days after each cut was made. Differently prepared samples were examined with light and electron microscopes. Three female bottlenose dolphin were implanted with nine different materials: high density polyethylene, Proplast II, urethane, copper, titanium, Copel, Inconel 671, Monel 400, and 416 stainless steel in the form of 20-mm long by 1.6-mm diameter rods inserted into the dorsal fin. Implant sites and control areas on each dolphin were biopsied. Each biopsy was histologically prepared and examined for mitotic activity.

SIGNIFICANT CONCLUSIONS: Bottlenose dolphin avoided oil slicks of any composition during the day and night by employing active stimulation, echolocation, and vision. Effects of gasoline on cell proliferation could not be distinguished from natural variation within a species. Lipid content was related to environmental temperature. Lack of any detectable antimicrobial properties of epidermal lipids indicated that lipid loss or damage would not render an animal susceptible to disease. Epidermal lipids were not affected by direct exposure to gasoline. The epidermal layer was an effective barrier to foreign antigens. Naphthalene bioaccumulation was highest in blubber of toothed

whales. Baleen fouling does result from oil films, but impacts were short term and reversible. Eight of the nine implanted materials were shed within three weeks; the remaining one, polyethylene, was not accepted by the tissue. Some hybrid material could be used in developing a suitable tagging material.

STUDY RESULTS: Surface oil avoidance tests revealed that bottlenose dolphin avoided 1-cm thick surface films regardless of type or ambient light conditions. Tactile stimulation appeared to override echolocation and chemoreception in detection of slicks. Epidermal lipid studies revealed preponderance of intracellular lipids, a unique cetacean characteristic. Long-term (35 h) gasoline exposure resulted in removal of these lipids. Lipid distribution and saturation within epidermal layers was directly related to ambient temperatures. Only one lipid extract preparation (from fin whale) suppressed growth of the bacterial pathogen *Erysipelothrix rhusiopathiae*. No Langerhans cells were found in cetacean epidermis, however, morphologically similar cells were detected in harp seal skin samples. The highest levels of naphthalene were in small toothed whales, particularly beluga and narwhal blubber which ranged from 6 to 21 ppm. No petroleum residue evidence was found in baleen samples from 27 whales. Experimental analyses of baleen oil fouling revealed that humpback baleen was most affected while gray whale samples were almost unaffected. Overall, baleen fouling was considered a short-term impact. Inflammatory response and wound healing in bottlenose dolphin epidermis did not include scab formation; a transformation barrier layer of epidermal cells served this purpose. The only percutaneously implanted material remaining after 12 weeks was porous polyethylene; eight other materials were extruded by the third week. There were zones of reactivity persisting around the implant, suggesting that the material had not been completely accepted.

STUDY PRODUCT(S): Geraci, J. R. and D. J. St. Aubin. 1985. Expanded Studies of the Effects of Oil on Cetaceans. A final report by the University of Guelph for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. Contract No. 14-12-0001-29169. 144 pp.

Geraci, J. R., D. J. St. Aubin, G. J. D. Smith, and B. D. Hicks. 1985. Cutaneous Response to Plastic and Metallic Implants of Potential Use for Marking Cetaceans. A final report by the University of Guelph for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. Contract No. 14-12-0001-29169. 120 pp.

Geraci, J. R. and D. J. St. Aubin. 1982. Study of the Effects of Oil on Cetaceans. A final report by the University of Guelph for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB83-1154991. Contract No. 14-12-0001-29169.

Other publications in the Canadian Journal of Zoology include Brown et al. (1983), Geraci et al. (1983), Smith et al. (1983), and St. Aubin et al. (1984).

*P.I.'s affiliation may be different than that listed for Project Manager(s).

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STUDY TITLE: Study of the Effects of Sound on Marine Mammals.

REPORT TITLE: Effects of Noise of Offshore Oil and Gas Operations on Marine Mammals--An Introductory Assessment. Vols. I and II.

CONTRACT NUMBER(S): BLM: IA0-05; MMS: 14-12-0001-29172.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Southern California; Cook Inlet.

FISCAL YEAR(S) OF PROJECT FUNDING: 1980; 1981.

COMPLETION DATE OF REPORT: September 1982.

COST(S): FY 1980: \$215,000; FY 1981: \$178,600; Cumulative Project Cost: \$393,600.

PROJECT MANAGER(S): E. Lindner.

AFFILIATION: Naval Ocean Systems Center.

ADDRESS: Marine Sciences Division, San Diego, California 92152.

PRINCIPAL INVESTIGATOR(S)*: R. Christensen, A. Church, R. Gales, J. Hoke, D. MacCormack, D. Schmidt, C. Turl.

KEY WORDS: North Atlantic; Southern California; Cook Inlet; endangered species; Baltimore Canyon; biology; marine mammals; sound; behavior; modeling; assessment; literature review.

BACKGROUND: To evaluate or predict potential noise and vibration problems caused by development activities, the U.S. Department of the Interior contracted a study to describe the acoustic environment near oil and gas operations and behavioral responses of associated marine mammals.

OBJECTIVES: (1) To determine and characterize various sounds emitted from oil and gas operations; (2) To characterize sounds emitted and perceived by various cetacean species; (3) To evaluate the sound spectra created by human activities which could disrupt behavior of cetaceans; (4) To determine the effects of a physical structure, such as a platform, on cetacean behavior; and (5) To propose mitigating measures which would eliminate or minimize the impact of offshore physical structures and associated human activities on cetaceans.

DESCRIPTION: Direct observation of cetacean behavior in the vicinity of Outer Continental Shelf (OCS) oil and gas operations was achieved by field teams using questionnaires, identification sheets, and interviews with platform personnel. A FORTRAN computer program was developed to manage anecdotal data. Field measurements of OCS operations were made using a hydrophone, preamplifier, and magnetic tape recorder. A graphic recorder was added to this system for continuous measurements (5 days). The hydrophone was capable of responding to 0.1-Hz signals. Recorder limitation was -3 dB at 15 Hz. Each tape sample was recorded on FM (0 to 2,500 Hz) and direct (100 to 30,000 Hz) channels. Recordings were taken from 18 structures including semi-submersible drilling units, fixed multi-legged drilling and/or production platforms, and a man-made island. Offshore sites were: Santa Barbara, California; Upper Cook Inlet, Alaska; and

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Baltimore Canyon off New Jersey. Data were analyzed for spectral content, source level, and duration. Data were transcribed from analog graphic outputs to spectrum plots of sound pressure spectrum level vs. frequency.

A literature review was completed in two phases: (1) Underwater noise from offshore operations, and (2) underwater hearing and sound production of marine mammals.

A source-path-receiver model was used to estimate detection of underwater sounds by marine mammals. The sound source was an oil drilling unit or platform. The path or sound propagation medium was water. Certain simplifying assumptions regarding sound attenuation in water were applied to the path and its boundaries prior to calculation of the model. For each sound receiver (animal), a particular frequency range threshold was determined considering noise discrimination capability of the animal, frequency component to be detected, and ambient sea noise (i.e., ship traffic, sea state, soniferous animals).

SIGNIFICANT CONCLUSIONS: Oil and gas operations produce significant underwater noise over a wide range of frequencies. Marine mammals can detect certain low frequency sounds from considerable distances. It was apparent that whales ignore or readily avoid platforms without appreciable behavioral alterations. It is also unlikely that platform noise will interfere with echolocation or acoustic communication in marine mammals.

STUDY RESULTS: Interview and sighting cards employed at Alaska and California platforms generated very little useful information; work pressures and overall inexperience were cited as primary reasons for this. The available reports indicated that whales were generally oblivious to platform operations. Only helicopters were reported to elicit a flight response in whales.

The acoustic environment around all 18 structures exhibited components above ambient sea noise. Low frequency (4 to 8 Hz) maximum line components occurred at structures engaged in drilling or production. Sound pressure levels of the highest level components of platform noise measured at a distance of 30 m were generally in the range of 110 to 130 dB re 1 micropascal. Of the 18 structures rated, two were rated noisy, 13 moderate, two quiet, and one (the man-made island) very quiet. Noise radiated by a structure depends on the materials, configuration, size, and shape of its underwater surfaces, type of machinery power, machinery balance, and many other factors. Environmental factors included water depth and bottom type. Support vessels also produced significant increases in noise (115 to 119 dB) levels mainly due to propeller cavitation.

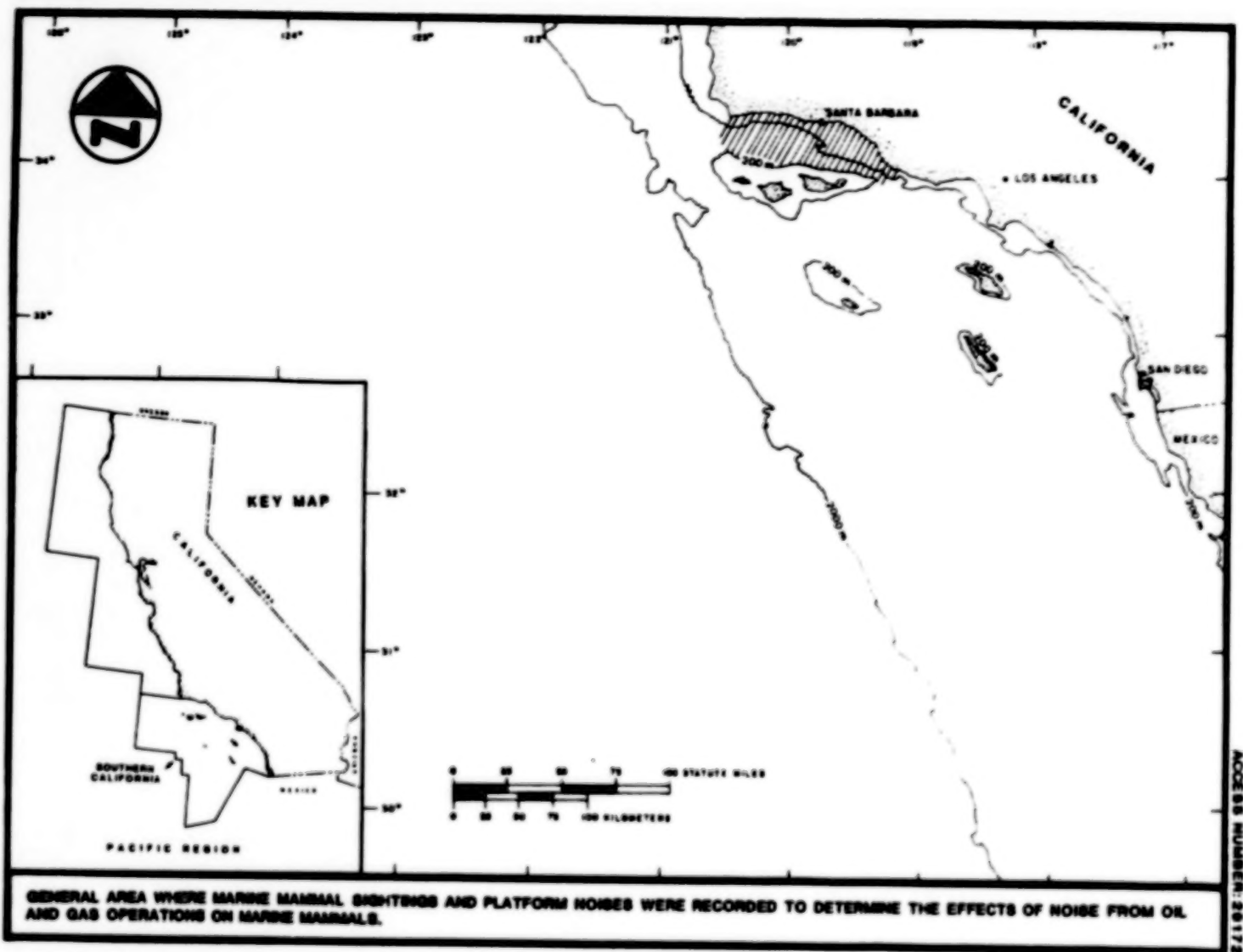
The source-path-receiver model predicted that low-frequency sounds emitted from noisy platforms may be detected at ranges on the order of hundreds of kilometers under optimal conditions. For all geographic locations studied, the range of sound detection by mysticetes, odontocetes, and pinnipeds should not exceed 185 km. Actual estimates for detections were 3,200, 1,372, and 137 m for Cook Inlet, Santa Barbara, and Baltimore Canyon, respectively. Sound levels between 143 to 180 dB above threshold would be uncomfortable for beluga whale, bottlenose dolphin, and harbor seal. Levels measured at various structures were generally well below 100 dB at 15 m. Echolocation by marine mammals occurs at much higher frequencies than sounds emitted by structures. Interference with acoustic communication is unlikely unless the receiving animal is extremely close to the platform and the sending animal is a considerable distance away.

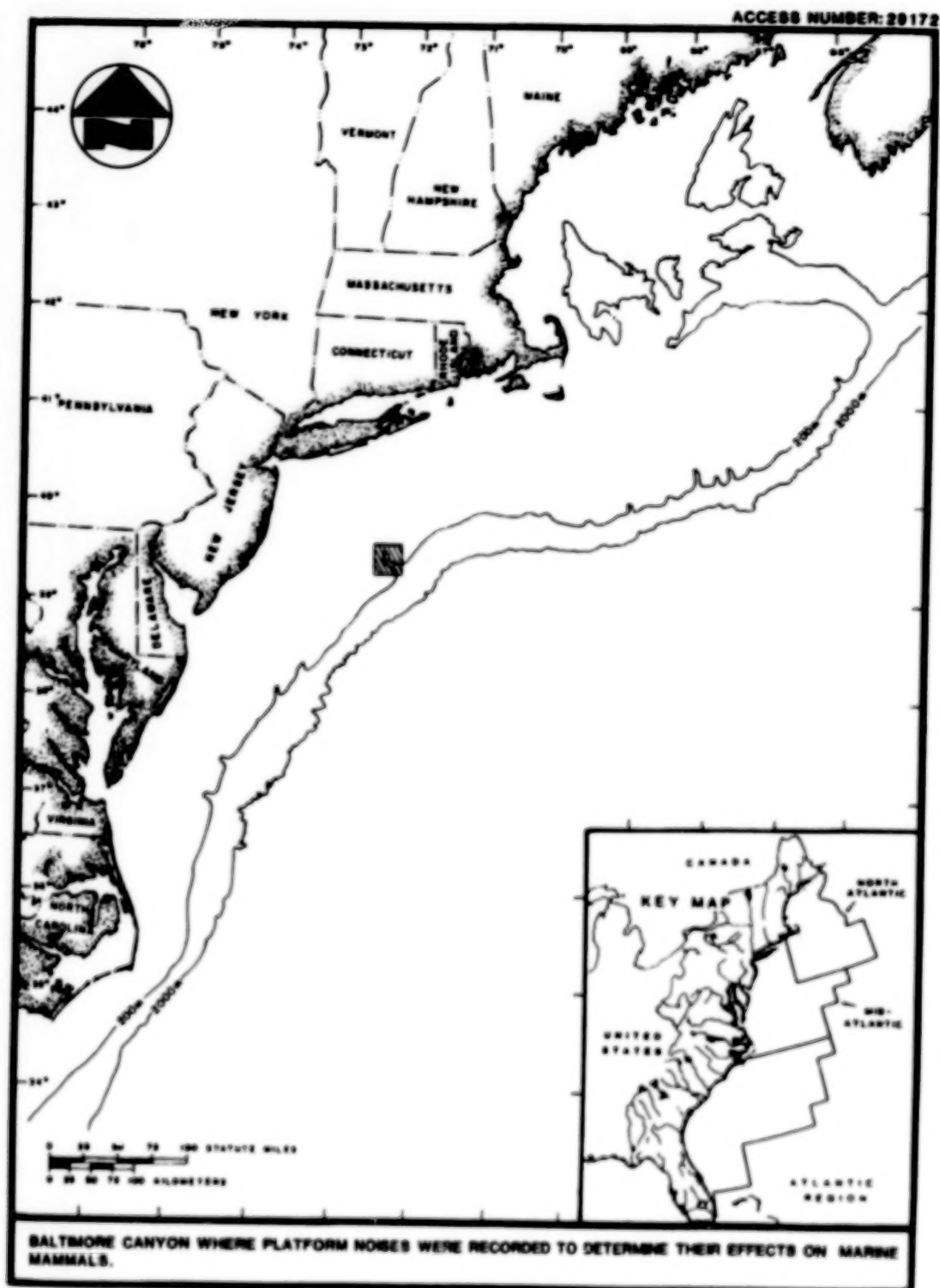
STUDY PRODUCT(S): Gales, R. S. 1982. Effects of Noise of Offshore Oil and Gas Operations on Marine Mammals--An Introductory Assessment. A report by Naval Ocean Systems Center for the

Access Number: 29172

U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY.
Vol. I - NTIS No. ADA123699; Vol. II - NTIS No. ADA123700. Contract No. AA851-IA0-05.

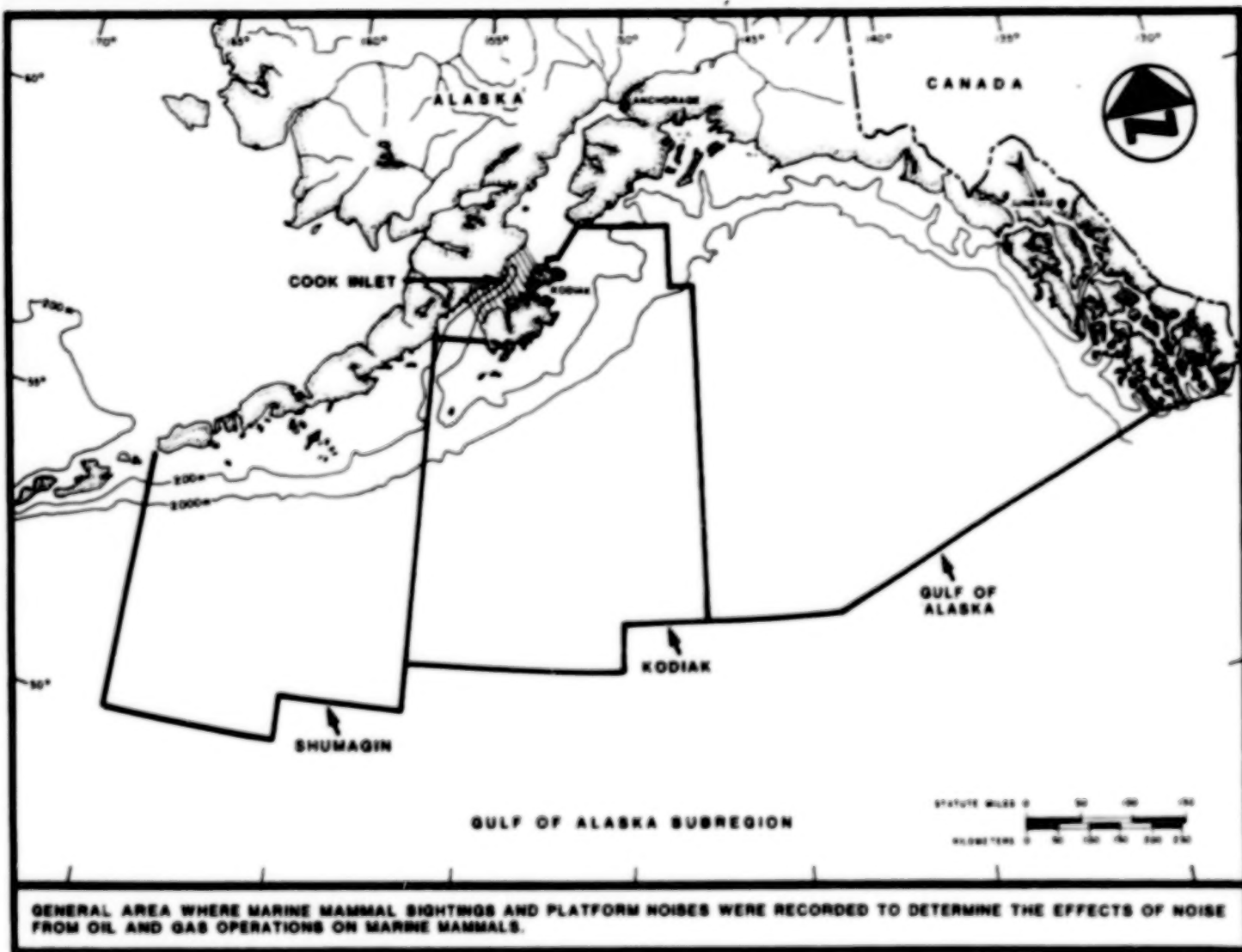
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IV **FATES & EFFECTS**

Fates and effects investigations are primarily studies of the physico-chemical and biological processes that affect spilled oil and studies of the impact of oil and gas discharges and spilled oil on important biological populations or communities. These studies have examined short-term effects in the vicinity of selected exploratory drilling rigs and long-term effects in regions where offshore oil and gas development activities have occurred for a prolonged time. This topic may also include projects that measure ambient levels of chemical contaminants in the environment.

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STUDY TITLE: Crude Oil Effects to Development Stages of the American Lobster.

REPORT TITLE: Crude Oil Effects to Developmental Stages of the American Lobster.

CONTRACT NUMBER(S): BLM: CT9-05; MMS: 14-12-0001-29165.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1979.

COMPLETION DATE OF REPORT: June 1982.

COST(S): FY 1979: \$119,848; **Cumulative Project Cost:** \$119,848.

PROJECT MANAGER(S): J. Capuzzo.

AFFILIATION: Woods Hole Oceanographic Institution.

ADDRESS: Woods Hole, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: J. Capuzzo.

KEY WORDS: North Atlantic; fates and effects; American lobster; Homarus; hydrocarbons; metabolism; larval stages; histopathology; juveniles; mortality; gas chromatography; respiration; bioaccumulation; sediment.

BACKGROUND: Increased interest in oil and gas exploration off the northeast coast of North America has focused concern on potential toxic effects of oil on commercially and ecologically important shellfish species, including the American lobster, Homarus americanus. The lobster has four planktonic larval stages that could be exposed to oil dispersed in surface waters. This study assessed potential effects of exposure to crude oil on larval and juvenile lobsters.

OBJECTIVES: (1) To assess the physiological effects of sublethal exposure to south Louisiana crude oil (SLCO) on all larval stages of the American lobster; (2) To assess the physiological effects of ingestion of an oil-contaminated food source on all larval stages; (3) To assess the physiological effects of chronic exposure to oil-contaminated seawater and sediments on juvenile lobsters; (4) To evaluate body burden and depuration of larval and juvenile lobsters exposed to oil in the above experiments; and (5) To evaluate histological aberrations of larval and juvenile lobsters exposed to oil in the above experiments.

DESCRIPTION: Three sets of experiments were conducted to address study objectives. One focused on physiological effects on all larval stages of chronic exposure to crude oil in seawater. A second set examined effects of exposure to oil in seawater and sediments on juvenile (post-larval) lobsters. A third set examined physiological effects of exposure to a contaminated food source on larval and early juvenile lobsters.

In the first set of experiments, the four larval stages were exposed to 0.25 ppm of SLCO for 96 h in a continuous, flow-through bioassay system consisting of 24 replicate 500-ml assay chambers. Survival, respiration, and ammonia excretion rates were measured daily, and animals were sacrificed

after 96 h for hydrocarbon (by gas chromatography) and histological analyses. Stage IV larvae were also exposed to SLCO for 96 h and transferred to clean seawater; survival and rates of respiration and ammonia excretion were determined after 96 and 168 h in clean seawater; and animals were sacrificed at 168 h for biochemical analyses. Additional data on larval survival and development were obtained using a larger (40 l) flow-through system for comparison with previously collected data.

Effects on juvenile lobsters of oil in water and sediments were evaluated by: (1) exposing Stage VII lobsters to 0.25 ppm SLCO in seawater for 78 days using the flow-through bioassay system; determining rates of respiration, ammonia excretion, molting, feeding, and survival at weekly intervals; and conducting hydrocarbon and histological analyses of lobsters sacrificed after 78 days; and (2) exposing Stage X lobsters to oil-contaminated sand in a flow-through system, and sampling sediments and lobsters weekly for histological (lobsters) and hydrocarbon (both sediment and lobsters) analyses.

Effects of exposure to a contaminated food source were examined by hatching brine shrimp in 0.25-ppm SLCO and supplying the brine shrimp to each lobster larval stage and to Stage V juveniles in the flow-through bioassay system. Rates of respiration and ammonia excretion were measured after 24 and 72 h. Survival and molting frequencies were also noted. Lobsters were sacrificed after 96 h for hydrocarbon analyses.

SIGNIFICANT CONCLUSIONS: Disruptions in the energetics of larval development were observed upon exposure to oil-seawater mixtures and to an oil-contaminated food source. Larval lobsters fed a contaminated food source showed earlier signs of stress than did those exposed to an oil-seawater mixture, although later larval stages of those exposed to oil-contaminated food showed some restoration of normal energetic patterns during exposure. In larval stages, hydrocarbon turnover was rapid and little accumulation was noted; larvae and early juveniles, when transferred to clean seawater, gradually resumed normal energetic patterns. Juvenile lobsters were less sensitive to oil-seawater mixtures than were larvae. However, juveniles were sensitive to oil-contaminated sediments and appeared to have longer retention times of hydrocarbons.

STUDY RESULTS: Exposure to crude oil mixed with seawater had no effect on the survival of any of the larval stages, and no aberrations in their histology were noted. However, respiration rates of Stage I larvae were reduced after 24 h of exposure, and those of all four larval stages were reduced after 72 h. Ammonia excretion rates were elevated in two larval stages after 72 h, and ratios of respiration to ammonia excretion were reduced in all stages after 24 h and greatly reduced after 72 h of exposure. Oil-exposed larvae had higher protein and lower lipid contents than did control larvae, and normal patterns of lipid metabolism were altered in the oil-exposed larvae. When early juveniles were transferred to clean seawater following a 96-h exposure, both respiration and ammonia excretion rates remained lower than those of control lobsters for at least 168 h afterward.

When larvae and early juveniles were fed oil-contaminated food, survival rates of two larval stages were slightly reduced after 72 h of feeding. Respiration rates were reduced in all except Stage I larvae after 24 h and in all stages after 72 h. Ammonia excretion rates were higher in all stages after 24 h and in all except Stage II larvae after 72 h. Ratios of respiration to ammonia excretion, however, increased between 24 and 72 h for later larval stages and the early juvenile stage, suggesting that metabolic adaptation was occurring in these animals.

Juvenile lobsters were unaffected by oil in seawater. However, when juveniles were exposed to oil-contaminated sediments, their respiration rates were reduced within 48 h. These rates remained lower for 30 days, by which time negligible levels of oil remained in the sediments. Juveniles accumulated hydrocarbons from oiled sediments, and apparently retained these hydrocarbons in their tissues longer than did larval lobsters.

STUDY PRODUCT(S): Capuzzo, J. M. 1982. Crude Oil Effects to Developmental Stages of the American Lobster. A final report by Woods Hole Oceanographic Institution for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB2117656. Contract No. AA551-CT9-05. 99 pp. + app.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*

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STUDY TITLE: Georges Bank Monitoring Program: Benthic Infauna - Year I.

REPORT TITLE: Georges Bank Benthic Infauna Monitoring Program.

CONTRACT NUMBER(S): BLM: CT2-07; MMS: 14-12-0001-29192.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982; 1983.

COMPLETION DATE OF REPORT: April 1983.

COST(S): FY 1982: \$2,158,359; FY 1983: \$1,007,127; Cumulative Project Cost: \$3,165,486.

PROJECT MANAGER(S): J. Neff.

AFFILIATION: Battelle New England Marine Research Laboratory.

ADDRESS: 397 Washington Street, Duxbury, Massachusetts 02332.

PRINCIPAL INVESTIGATOR(S)*: J. Blake, J. Grassle, N. Maciolek-Blake, J. Neff, H. Sanders.

KEY WORDS: North Atlantic; Georges Bank; Oceanographer Canyon; Lydonia Canyon; faes and effects; infauna; epifauna; benthos; sediment; grain size; benthic photographs; seasonality; community; exploratory drilling; monitoring.

BACKGROUND: The Georges Bank is one of the most productive commercial fishery areas in the world. As interest increased in exploring for oil and gas reserves in the Georges Bank area, substantial concern was expressed by several groups including environmentalists and the commercial fishing industry. These groups felt that petroleum exploration and possible subsequent development activities might seriously damage the bank's complex and highly productive ecosystem. Because of these concerns, a Biological Task Force (BTF) for Lease Sale 42 was established. One purpose of the BTF was to design environmental studies and monitoring programs to detect the possible early warning signs of environmental deterioration on Georges Bank. The Georges Bank Benthic Infauna Monitoring Program was one portion of a multidisciplinary monitoring program recommended by the BTF. The benthic infauna monitoring program addressed whether animal populations in the sediments changed during various stages of oil and gas exploration activity arising from Lease Sale 42.

OBJECTIVES: (1) To determine both the near-field, short-term and regional, long-term environmental impacts of oil exploration on the benthic infaunal community.

DESCRIPTION: Forty-six collecting stations were established on or adjacent to Georges Bank. These consisted of regional long-term assessment stations located: (1) at opposite sides of the bank; (2) in transects of three stations per transect; (3) along isobaths; and (4) at sites where drilling muds and cuttings might accumulate. Near-field impacts were assessed with three stations located from 200 to 2,000 m up and down current from the drilling rig in Block 410. A larger 29-station array in a radial pattern was placed around an exploratory drilling rig in Block 312. All stations were sampled in July and November 1981 and February and May 1982. At each station, six replicate

biological samples and three replicate chemical samples of undisturbed bottom sediments were collected with 0.04 and 0.1 m² VanVeen grab samplers, respectively. Biological samples were sieved through a 0.3-mm sieve. Chemical samples were frozen. Samples for sediment grain size analysis and bottom photographs were taken at each station. In the laboratory, each benthic sample was transferred to 70% alcohol, stained with rose bengal, and identified to the lowest possible taxon. Wet biomass was determined separately for each species. Statistical techniques included agglomerative clustering, similarity analysis by the Normalized Expected Species Shared (NESS) and Bray-Curtis techniques, and Shannon-Wiener diversity calculations. Hurlburt's modification of the rarefaction method was used to predict the number of species in a random sample without replacement. If available, six frames from each station per cruise were analyzed for microtopographic features and densities of visible epifauna.

SIGNIFICANT CONCLUSIONS: Results are presented from the sampling and subsequent analyses conducted during the first year of the multi-year Georges Bank Monitoring Program. Based on the analysis of biological specimens collected from the seafloor, researchers concluded that there were no significant changes in community structure attributed to oil and gas drilling activities on Georges Bank. Chemical analysis of sediment failed to identify, with any significant level of confidence, previous drilling activities as the source of noted increases in the concentration of select sediment-bound trace metals. Differences in the biological communities identified during the first year were attributed to the variable water depths and sediment textures encountered during sampling. No evidence of biological impact could be attributed to an estimated 1,600 to 1,800 MT of drilling muds and cuttings discharged in Block 410. No accumulation of muds and cuttings was noted in any of the benthic photographs.

STUDY RESULTS: In general, no significant changes in benthic community structure could be related to drilling activities. The variations in community structure identified during this study were attributed to differences in depth and substrate type. A total of 783 species were identified from infaunal grab samples taken during four seasonal cruises. Polychaetes represented 306 of the species collected and accounted for 39.1% of all taxa identified. Arthropods were represented by 159 species and accounted for 20.3% of the identified taxa. Molluscs accounted for 132 species, 16.6% of the fauna. Stations located along the same depth interval were similar in terms of dominant species. Stations at the 60-m contour were dominated by an archiannelid Polygordius sp. A, a bivalve Tellina agilis, and the amphipods Pseudunciola obliqua and Protohaustorius wigleyi. Along the 80-m depth range, syllid polychaetes and the oligochaete Phallodrilus coeloprostratus dominated. Ampelisca agassizi, Polygordius sp. A, and Protodrilus gaspeensis dominated the 100-m contour. In the deeper stations on the southern slope of the bank and in Oceanographer Canyon, Ampelisca agassizi was dominant, but this species was less abundant in Lydonia Canyon and the stations in the 140 to 145 m depth range.

The average number of individuals per station varied substantially from station to station. The maximum density at any station was 12,000 individuals per 0.04 m². Population densities were generally lowest during winter. However, several stations were characterized by marked population reductions during late spring while others were characterized by reductions in late summer and fall. Molluscs and echinoids dominated the biomass measurements because their shells and endoskeletons were included in the weights.

Statistical analyses indicated lower diversities in shallower water and higher diversities in deeper water. This pattern did not appear to shift significantly with the seasonality of sampling.

Clustering analysis showed that each replicate within a station clustered first with the other replicates from the same station before joining those of other stations. This comparability within stations allowed detection of small changes in benthic community characteristics. No changes in the benthic community at any station on the bank were detected in relation to drilling activities. Stations clustered together primarily on the basis of depth and secondarily on sediment type.

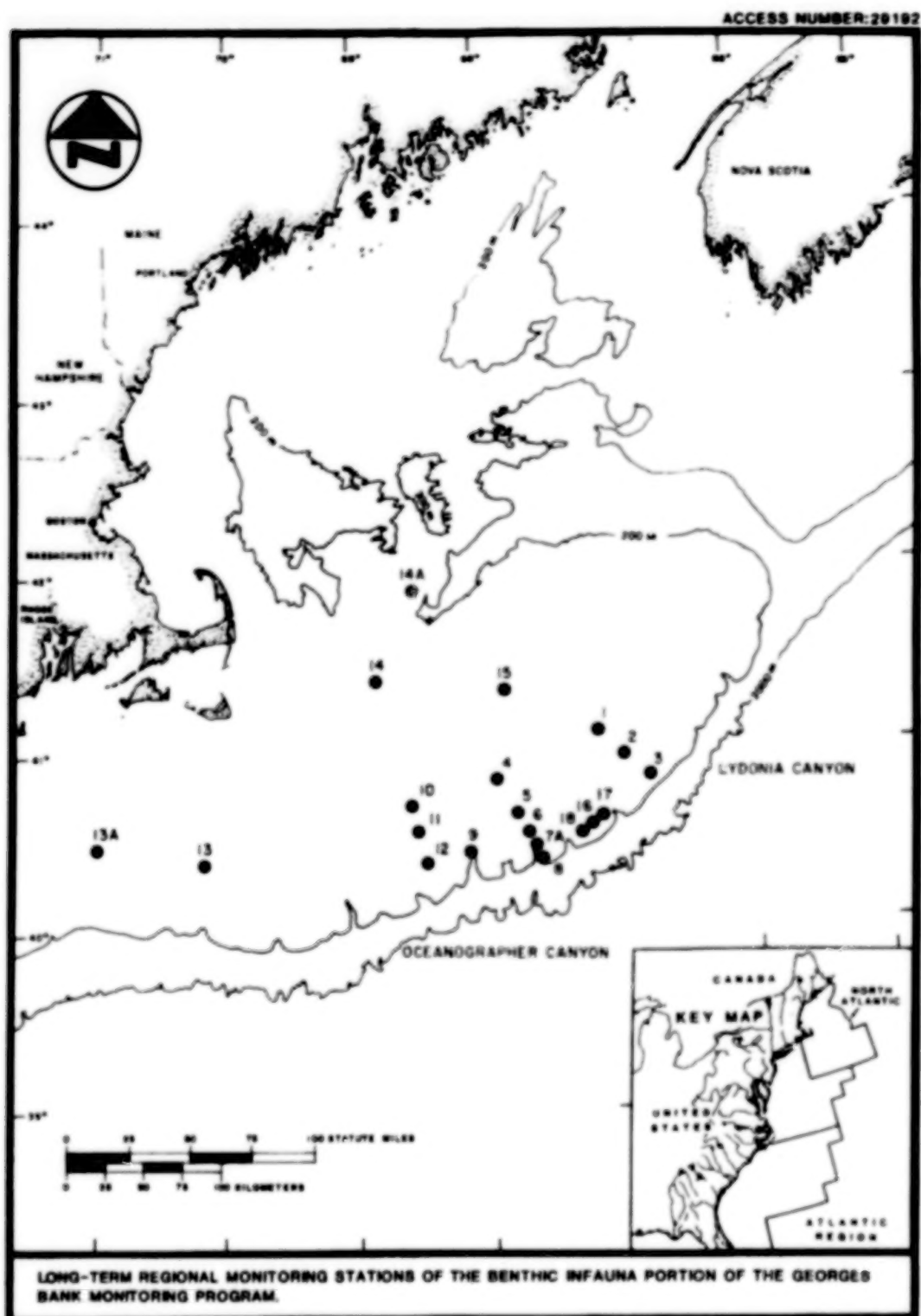
Barium (Ba) concentrations increased in the bulk sediments at several of the site-specific stations. Using these Ba levels as the basis for a gradient, the total numbers of individuals and densities of 24 species abundant at these stations were plotted. Certain patterns of decrease and recovery in the densities of these species were noted in stations near and down current from the drilling in Block 312 by the semisubmersible ROWAN MIDLAND. Because of the large standard deviation associated with each mean, it was not possible to attach a high level of statistical significance to these observed patterns. Population differences observed in Block 410 were attributed to differences in substrate type. No evidence of biological impact could be attributed to an estimated 1,600 to 1,800 MT of drilling muds and cuttings discharged in Block 410.

Sediment on Georges Bank was 95% sand. To the south of the bank, the percentages of silts and clays increased, indicating that these areas received increased deposition. No accumulation of drilling muds and cuttings was noted in any of the photographs.

STUDY PRODUCT(S): Blake, J. A., J. F. Grassle, N. Maciolek-Blake, J. M. Neff, and H. L. Sanders. 1983. Georges Bank Benthic Infauna Monitoring Program. A final report by Battelle New England Marine Research Laboratory and Woods Hole Oceanographic Institution for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. Vol. I - NTIS No. PB83-204511; Vol. II - NTIS No. PB83-204529. Contract No. 14-12-0001-29192. 256 pp.

A reference biological specimen collection and benthic photographs are maintained by Battelle New England Marine Research Laboratory, Duxbury, Massachusetts.

**Pl.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments - Year 1.

REPORT TITLE: The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments.

CONTRACT NUMBER(S): BLM: IA2-18; MMS: 14-12-0001-29194.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982.

COMPLETION DATE OF REPORT: December 1982.

COST(S): FY 1982: \$324,847; **Cumulative Project Cost \$324,847.**

PROJECT MANAGER(S): M. Bothner.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

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PRINCIPAL INVESTIGATOR(S)*: P. Aruscavage, M. Bothner, D. Brewster, F. Brown, E. Campbell, A. Dorrazpl, Jr., M. Doughten, R. Johnson, C. Parmenter, M. Pickering, R. Rendigs.

KEY WORDS: North Atlantic; Georges Bank; Gulf of Maine; Lydonia Canyon; fates and effects; trace metals; sediment; exploratory drilling; monitoring; grain size.

BACKGROUND: Substantial concern has been expressed by environmentalists and the commercial fishing industry that oil and gas exploration and possible development on Georges Bank could seriously damage the bank's complex and highly productive ecosystem. Because of these concerns, a Biological Task Force (BTF) was established for Lease Sale 42 which encompassed lease blocks from Georges Bank. One purpose of this BTF was to design environmental studies and surveys that would provide early warning of possible adverse environmental effects from petroleum exploration and development activities. The Georges Bank Monitoring Program was designed to address concerns related to initial petroleum exploration on Georges Bank, specifically the fates and effects of discharges (primarily drilling fluids and cuttings) from the drilling efforts resulting from Lease Sale 42.

OBJECTIVES: (1) To determine concentration levels of trace metals in sediments prior to and after drilling activities on Georges Bank; and (2) To quantitatively assess the magnitude of changes related to petroleum exploration.

Access Number: 29194

DESCRIPTION: The data base included 18 regional stations located across Georges Bank, 29 site-specific stations located around a drillsite in Block 312, and three stations located around a drilling rig in Block 410. Four cruises were conducted. A pre-drilling cruise occurred in July 1981. The remaining cruises occurred in November 1981 and in February and May 1982. Samples were taken with a 0.1-m² stainless steel VanVeen grab sampler with Teflon coating on all contact surfaces. Extensive precautions were taken to prevent sample contamination. Samples were dried to a constant weight at 40°C in a Teflon-coated oven with a filtered nitrogen atmosphere. Grain size analysis was performed by a Rapid Sediment Analyzer and the gravimetric determination of silts and clays by filtering. Trace metals analyzed were: aluminum (Al), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn). Organic carbon was analyzed only on the first cruise. Analytical precision was determined by periodically analyzing five replicate aliquots taken from a single sample and determining the coefficients of variation. Accuracy was determined by comparisons with standard solutions.

SIGNIFICANT CONCLUSIONS: Analysis of select trace metals in the unfractionated sediment samples from Georges Bank indicated increases in Ba levels up to 2,000 m from the drillsite following drilling activity. No increases in the concentrations of other trace metals were detected in bulk sediments. Subsequent analysis of the sediment fine fraction, typically representing less than 3% of the total sediment, increased Ba concentrations by a factor of 22 to 36 times for pre-drilling measurements. Highest concentrations, however, were only equivalent to average crustal material values.

STUDY RESULTS: The sediments on Georges Bank were typically greater than 95% sand with minor amounts of gravel, silts, and clays. The sand was quartzose, medium to coarse grained. Concentrations of silts and clays were generally less than 2% on the bank itself, but higher (4 to 18%) in the Gulf of Maine, at Lydonia Canyon (2 to 4%), and south of Nantucket Island (38 to 97%).

The gravel fraction was variable throughout the study area (0 to 30%). Drilling cuttings were observed within the gravel fractions from stations within 200 m of the two drillsites monitored. No evidence of cuttings was found farther than 200 m from the drilling rigs.

Concentrations of metals in average crustal material and in average sandstone were compared to the pre-drilling metal concentrations. With the exception of Pb, the highest concentration observed in pre-drilling samples was below concentrations found in mean crustal rocks, indicating the sediments from Georges Bank were uncontaminated by heavy metals. The observed increase in Pb was attributed to the use of tetraethyl lead in gasoline. One station south of Nantucket Island, characterized by a higher percentage of fine sediments (56% sand, 23% silt, 21% clay), was also characterized by a higher concentration of heavy metals, suggesting that this area may be a modern sink for pollutants that are reactive with fine-grained, organic-rich sediments.

Ba (present in barite, a major component of drilling muds) increased by a factor of 3.5 in the bulk (unfractionated) sediments within 200 m of the drillsite in Block 410. Average Ba concentrations rose from 30 to 107 ppm. A small increase was observed 2,000 m from the drillsite in this block. In Block 312, where the intensive site-specific survey was conducted, Ba concentrations in bulk sediments increased by a factor of 2.3 (from 40 to 91 ppm) as a result of drilling. Increases of small magnitude were observed up to 6 km from the rig. It is important to note that Ba concentrations in excess of 100 ppm were measured at Georges Bank stations even before drilling began. No

drilling-related changes in the concentration of Cr or other metals were observed in bulk sediments from Block 312 or 410.

Separation and analysis of the sediment fraction finer than 0.062 mm, which typically represented less than 3% of the total sediments at Georges Bank, improved the ability to detect Ba increases due specifically to drilling discharges. Ba in the fine sediments of Block 410 increased from the pre-drilling level by a factor of 36 (242 to 8,640 ppm). In Block 312, a Ba increase of 22 times the pre-drilling level was reported from the fine sediments. Increases in Al, Cr, Cu, and Hg in the fine sediment fractions at Block 410 were reported. The highest concentrations measured, however, were only equivalent to average crustal material values.

Concentrations of Al, Ba, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Ni, V, and Zn in the surface sediments of Georges Bank, both before and after drilling, are low compared to average crustal abundances and are characteristic of unpolluted, coarse grained sediments found in other areas of the continental shelf. No drilling-related changes in the concentrations of Cr or other metals were observed in the bulk sediments from Block 312 or 410 where exploratory wells were drilled.

STUDY PRODUCT(S): Bothner, M. H., R. R. Rendigs, E. Campbell, M. W. Doughten, P. J. Aruscavage, A. F. Dorrzapf, Jr., R. G. Johnson, C. W. Parmenter, M. J. Pickering, D. C. Brewster, and F. W. Brown. 1982. The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments. A final report by the U.S. Department of the Interior, U.S. Geological Survey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB83-174888. Contract No. AA851-IA2-18. 62 pp.

**PI.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna from Georges Bank.

REPORT TITLE: Georges Bank Monitoring Program: Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna.

CONTRACT NUMBER(S): BLM: CT2-33; MMS: 14-12-0001-29198.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982; 1983.

COMPLETION DATE OF REPORT: December 1982.

COST(S): FY 1982: \$100,000; FY 1983: \$3,941; **Cumulative Project Cost: \$103,941.**

PROJECT MANAGER(S): J. Payne.

AFFILIATION: Science Applications, Inc.

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PRINCIPAL INVESTIGATOR(S)*: J. Payne.

KEY WORDS: North Atlantic; Georges Bank; fates and effects; hydrocarbons; trace metals; sediment; infauna; benthos; fish; monitoring; exploratory drilling.

BACKGROUND: Based on the April 1981 recommendations of the Georges Bank Biological Task Force, the Georges Bank Monitoring Program was implemented by the Minerals Management Service in July 1981 to determine the potential impact of exploratory drilling activities on benthic communities in the Outer Continental Shelf (OCS) Lease Sale 42 area of Georges Bank. Benthic environments are potential sinks for discharged drilling fluids and cuttings, and benthic organisms are particularly susceptible to exposure to these materials because of their relative immobility. Therefore, one major goal of this program was to identify and document immediate and long-term changes in hydrocarbon and trace metal levels in sediments and epifauna as a function of drilling activities and proximity to exploratory platforms. Such information is important in interpreting potential impacts on benthic communities.

OBJECTIVES: (1) To determine if there was evidence of petroleum hydrocarbon contamination of bottom sediments and fauna at selected sites in the Georges Bank Lease Sale 42 area, and if so, whether or not the source of contamination could be associated with exploratory drilling activities; and (2) To determine if there was evidence of trace metal contamination of benthic fauna at selected

sites in the Georges Bank Lease Sale 42 area, and if so, whether or not the sources of that contamination could be associated with exploratory drilling activities.

DESCRIPTION: Hydrocarbon and trace metal samples were collected and analyzed from a site-specific array of 29 stations located around an exploratory drilling rig in Block 312 and from a series of regional stations located throughout the Georges Bank area. Hydrocarbon analyses of selected drilling fluids, benthic sediments, and epifaunal tissue were conducted. Trace metal analyses were made of benthic fauna. Quarterly samples were taken. Sediments analyzed for hydrocarbons were collected in replicates of three with a 0.1-m² Teflon-coated VanVeen grab sampler. Collections of benthic epifauna were made in two ways: (1) filter feeders were collected using a modified rocking chair dredge; and (2) predators and demersal fishes were collected with a 10-m otter trawl.

Following extraction, sediment and tissue samples were screened using a synchronous scanning ultraviolet fluorescence technique. When evidence of hydrocarbon contamination was detected, more detailed analyses using capillary gas chromatography and gas chromatography/mass spectrometry were conducted. Trace metal analysis for aluminum (Al), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn) were conducted on selected tissue samples from benthic fauna.

SIGNIFICANT CONCLUSIONS: Hydrocarbon analyses of sediments and tissues from samples collected in the Georges Bank area indicated the presence of aliphatic and aromatic fractions, a majority of which were attributable to non-drilling related activities of man. Results indicated that there was no significant accumulation of aliphatic or aromatic hydrocarbons originating from drilling operations in the sediments adjacent to the drillsite. There was little or no evidence to support the hypothesis that drilling-associated hydrocarbons had accumulated in the tissues of test species. Analyses of select trace metals present within biota failed to identify increases when compared to ambient (pre-drilling) levels.

STUDY RESULTS: The highest and most variable aliphatic and aromatic hydrocarbon levels were observed in the area down current from Georges Bank known as the Mud Patch. This area, believed to be a depositional site for sediments, was characterized as having the finest grain size of any stations examined. The majority of the hydrocarbons detected here were believed to be from biogenic sources including marine algae and terrestrial plants. Aromatic hydrocarbons were thought to come from atmospheric fallout of combustion products, chronic low level inputs from sewage and waste water disposal, and weathered petroleum from tankers and shipping related discharges. Overall, aromatic hydrocarbon levels were extremely low and essentially constant over time at the benthic stations sampled. There were significant differences in absolute aromatic hydrocarbon levels between stations. There was no significant accumulation of aliphatic or aromatic hydrocarbons from exploratory drilling activities in Block 312, but this was attributed to the scouring and winnowing process of the currents in that area.

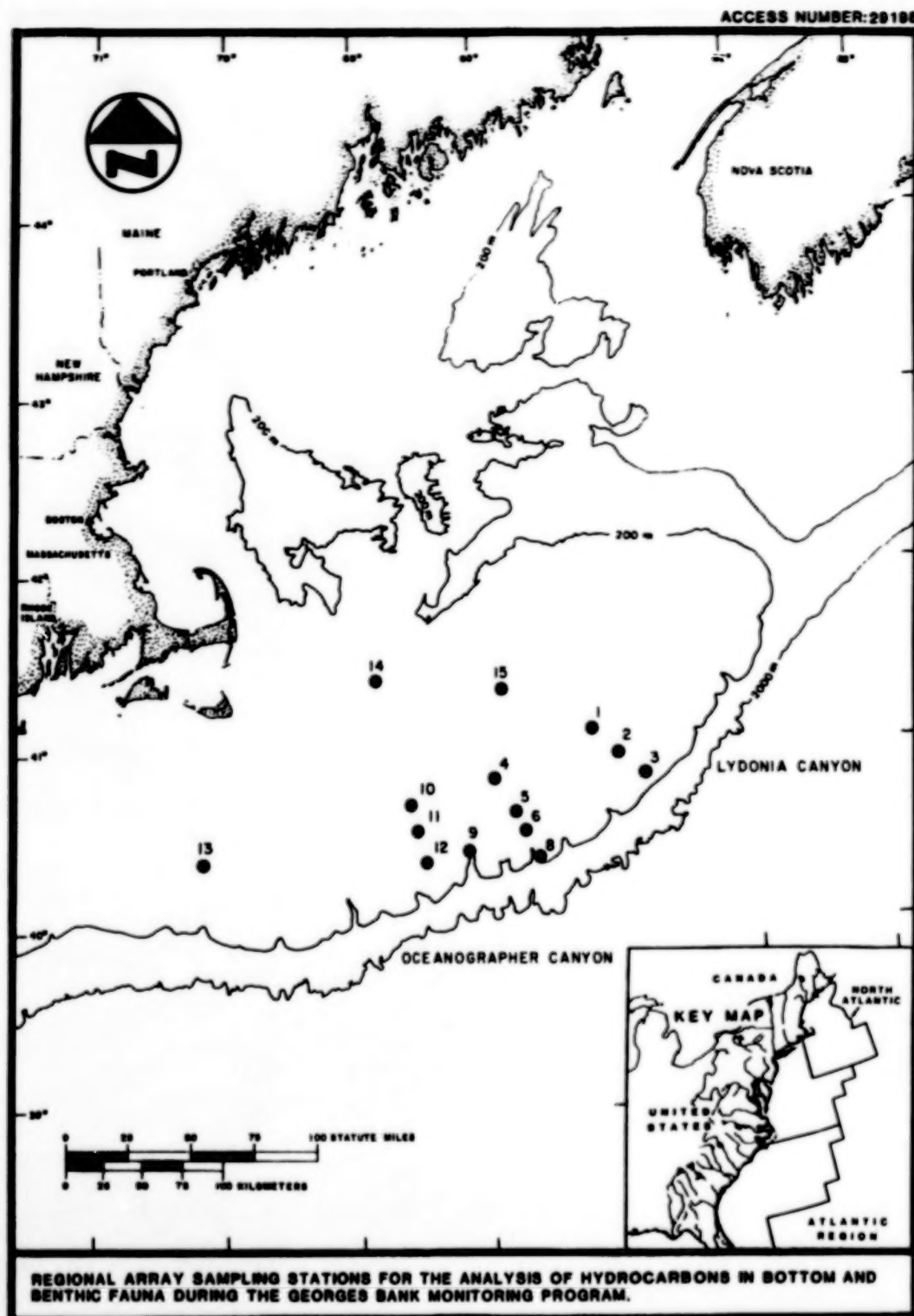
Analyses of four drilling fluid samples obtained from the semi-submersible drilling rig in Block 312 showed the presence of hydrocarbons in the range of 23 to 480 mg l⁻¹. Comparisons of the chromatographic profiles of the drilling fluids hydrocarbon component with sediment sample extracts from both site-specific and regional stations showed little evidence to suggest any drilling fluid accumulation.

There was little or no evidence to suggest that any hydrocarbon compounds associated with drilling fluids were accumulating in the tissues of the species analyzed. One sample of the black clam, Arctica islandica, yielded a selected ion monitoring profile which suggested that trace levels ($<1 \text{ ng g}^{-1}$ dry weight) of alkyl-substituted polynuclear aromatic hydrocarbons common to drilling fluids may have been present; however, the chromatogram of the aliphatic fraction showed no evidence of the characteristic profiles observed in drilling fluid analyses.

No evidence of change in the levels of trace metals present within the biota could be found during the four cruises of this monitoring program. Furthermore, there were no significant changes in levels of Cd, Cr, Cu, Fe, Ni, Pb, and Zn in tissue samples of A. islandica collected during this program when compared to those collected during the 1977, New England OCS Environmental Benchmark Program.

STUDY PRODUCT(S): Payne, J. R., J. L. Lambach, R. E. Jordan, G. D. McNabb, Jr., R. R. Sims, A. Abasumara, J. G. Sutton, D. Genero, S. Gagnet, and R. F. Shokes. 1982. Georges Bank Monitoring Program: Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna. A final report by Science Applications, Inc. for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. Vol. I - NTIS No. PB83-160778; Vol. II - NTIS No. PB83-180736. Contract No. AA851-CT2-33. 339 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Georges Bank Monitoring Program: Analysis of Hydrocarbons in Bottom Sediments and Hydrocarbons and Trace Metals in Benthic Fauna.

REPORT TITLE: Georges Bank Monitoring Program: Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna During the Third Year of Monitoring.

CONTRACT NUMBER(S): MMS: 14-12-0001-30001.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1983; 1984.

COMPLETION DATE OF REPORT: January 1985.

COST(S): FY 1983: \$145,764; FY 1984: \$146,257; Cumulative Project Cost: \$292,021.

PROJECT MANAGER(S): J. Payne.

AFFILIATION: Science Applications International Corporation.

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PRINCIPAL INVESTIGATOR(S)*: J. Payne.

KEY WORDS: North Atlantic; Georges Bank; fates and effects; hydrocarbons; trace metals; sediment; infauna; bioaccumulation; grain size; monitoring; benthos; drilling discharges; exploratory drilling.

BACKGROUND: The Georges Bank Monitoring Program, initiated in 1981 and funded by the U.S. Department of the Interior, sought to assess potential impacts of exploratory drilling activities on Georges Bank. The benthic environment was of particular concern with regard to potential long-term impacts of discharged drilling fluids and cuttings. Trace metal and hydrocarbon accumulation in sediments and benthic fauna were of particular interest. Therefore, these parameters were the subject of a three-year monitoring program. This report contains the results from the third year of monitoring.

OBJECTIVES: (1) To determine the quantities and distribution of hydrocarbons in bottom sediments from selected sites in the Lease Sale 42 area; (2) To determine whether there is any evidence of petroleum hydrocarbon contamination of bottom sediments, and whether the source of contamination is associated with exploratory drilling operations; (3) To determine the quantities and distribution of hydrocarbons and selected trace metals in benthic fauna; and (4) To evaluate long-term trends in hydrocarbons and trace metal concentrations by integrating the results from each year of the monitoring program.

DESCRIPTION: Samples of surficial sediments and benthic fauna were collected for hydrocarbon and trace metal analyses from a site-specific array of stations located near the exploratory rig, ROWAN-MIDLAND, on Block 312 and from a series of regional stations located throughout the Lease Sale 42 area. Samples collected quarterly from July 1981 to June 1984 at each regional station and

at site-specific stations were examined for hydrocarbons. Samples of the target organism were collected from site-specific and regional stations for analysis of tissue hydrocarbon and trace metal burdens. Sediment and benthic faunal samples were collected using Van Veen grab samplers. Sediment samples were extracted and screened for total aromatic hydrocarbon levels using a synchronous scanning ultraviolet/fluorescence technique which screens for specific classes of mono-, di-, and polycyclic aromatics. Extracts containing relatively high levels of di- and tricyclic polynuclear aromatics that are characteristic of drilling discharges were further analyzed using flame ionization detector gas chromatography and gas chromatography/mass spectroscopy. Hydrocarbons extracted from tissue samples of the black clam, *Arctica islandica*, were screened by ultraviolet/fluorescence then further analyzed with flame ionization detector gas chromatography. Tissues (gill, foot, and hepatopancreas) were analyzed both separately and compositely. Aliquots of the tissue samples were digested separately for analyses of aluminum (Al), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), nickel (Ni), and zinc (Zn) by flame and flameless atomic absorption spectrometry and for analysis of mercury (Hg) by cold vapor atomic absorption spectrometry. Tissue levels of barium (Ba) and vanadium (V) were analyzed using neutron activation analysis.

SIGNIFICANT CONCLUSIONS: Concentrations of hydrocarbons in Georges Bank sediments were related to grain size; highest concentrations were associated with fine-grained sediments. Aromatic hydrocarbon concentrations in the study area were consistent with previously recorded levels at both regional and site-specific stations. No evidence of long-term accumulation of petroleum hydrocarbons in near-rig sediments was apparent during the monitoring program. There was short-term deposition of discharged drilling fluids containing oil-based additives. No uptake or accumulation of drilling fluid constituents was detected in analyzed faunal tissues. Trace metal and hydrocarbon levels were consistently low and complied with previously recorded background levels. Evidence that areas of active sediment deposition act as eventual sinks for portions of discharged wastes was not provided during the monitoring program. Dilution from other sources of contamination were thought to obscure identification of inputs from localized sources such as drilling rigs.

STUDY RESULTS: Total aromatic hydrocarbons analyzed during the third year ranged from approximately 0.2 to 0.5 mg g dry wt⁻¹. Concentration of total aromatic hydrocarbons before drilling operations was 0.100 ug g dry wt⁻¹; during drilling, measured levels increased to 0.430 ug g dry wt⁻¹ and remained at 0.400 ug g dry wt⁻¹ for two years following drilling. Chromatographic profiles of sediments collected prior to drilling indicated the absence of petroleum contamination indicators. The presence of odd n-alkanes and a large unresolved complex mixture suggested petroleum contamination during and after drilling. Concentrations of aromatic hydrocarbons were highest at an area of active sediment deposition and varied little over time. The aromatic fraction at this station included polynuclear aromatics such as phenanthrene, fluoranthene, chrysene, and benzo-fluoranthrene. These compounds indicated low-level petrogenic accumulations in the sediments, however, pyrogenic and biogenic sources may also contribute.

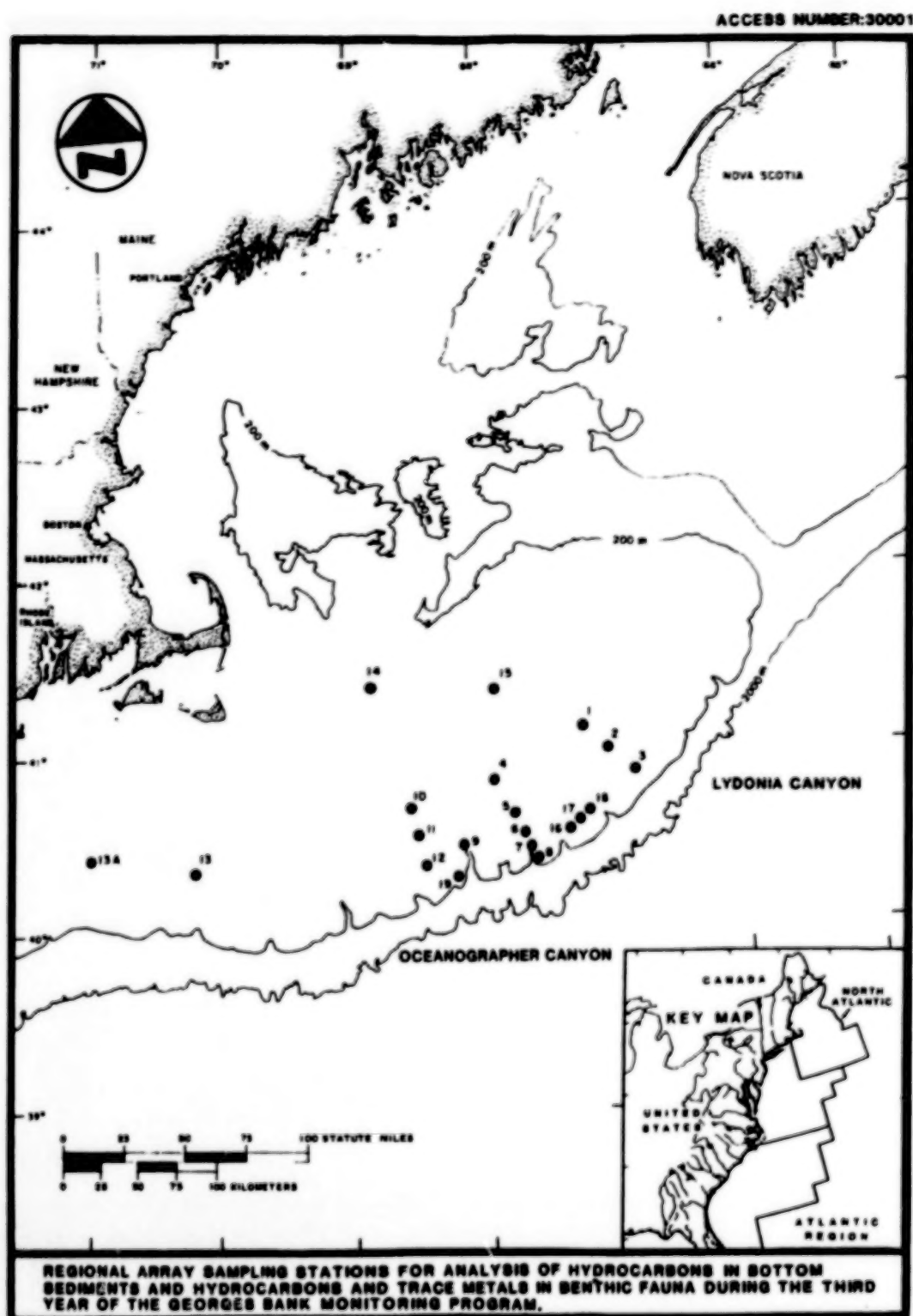
Hydrocarbons in *A. islandica* ranged from 3.3 to 4.5 ug g dry wt⁻¹ with a mean value of 4.0 ug g dry wt⁻¹. Concentrations of total aromatic hydrocarbons in individual and composite tissue samples ranged from 19 to 58 ug g dry wt⁻¹. A comparable sample collected one month after drilling operations terminated had a level of 2.6 ug g dry wt⁻¹. Patterns of distribution and abundance of hydrocarbons in organisms were difficult to detect due to low numbers of samples collected during the monitoring program. Most hydrocarbons identified in *A. islandica* tissue were biogenic (e.g.,

aldehydes, branched alcohols, fatty acid methyl esters, sterols, and sterenes). Marine oil pollution index values were low and also reflected biogenic character. No evidence of bioaccumulation of petroleum-contaminated particles in A. islandica was found, however, contaminant depuration by the clams was unknown.

Trace metal accumulation in A. islandica tissues was also not found during the monitoring program. Tissue Ba levels ranged from 1.8 to 2.6 ug g dry wt⁻¹ from site-specific stations. Slight increases in tissue Ba concentrations were recorded during drilling operations. Comparisons between pooled, organ-specific tissue indicated that concentrations of most metals in gill tissue were consistently higher than similar levels in foot tissue. Sufficient sample sizes were lacking from which to determine spatial and temporal variability in trace metal concentrations.

STUDY PRODUCT(S): Payne, J. R., J. L. Lambach, G. H. Farmer, C. R. Phillips, M. K. Beckel, J. G. Sutton, and R. R. Sims, Jr. 1985. Georges Bank Monitoring Program: Analysis of Hydrocarbons in Bottom Sediments and Analysis of Hydrocarbons and Trace Metals in Benthic Fauna During the Third Year of Monitoring. A final report by Science Applications International Corporation for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-30001. 105 pp.

**Pl.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Second Year Monitoring Period.

REPORT TITLE: The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Second Year of Monitoring.

CONTRACT NUMBER(S): MMS: 14-12-0001-30025.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1983.

COMPLETION DATE OF REPORT: December 1983.

COST(S): FY 1983: \$317,587; Cumulative Project Cost: \$317,587.

PROJECT MANAGER(S): M. Bothner.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

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PRINCIPAL INVESTIGATOR(S)*: M. Bothner, E. Campbell, M. Doughten, J. Gillison, R. Johnson, C. Parmenter, M. Pickering, R. Rendigs.

KEY WORDS: North Atlantic; Georges Bank; Gulf of Maine; Lydonia Canyon; fates and effects; trace metals; sediment; monitoring; exploratory drilling; benthos; grain size; transport; drilling discharges.

BACKGROUND: Lease Sale 42 opened the Georges Bank area for oil and gas exploration. Public concerns were expressed regarding the environmental safety of Georges Bank, one of the world's most productive fishing grounds. In 1981, the Georges Bank Monitoring Program was established as a multidisciplinary program designed to monitor contaminant levels before, during, and after exploratory drilling operations. This report describes the monitoring results for sediment trace metals from the second year of the monitoring program.

OBJECTIVES: (1) To determine the extent of trace metal accumulation in both near-field and far-field sediments; and (2) To relate the findings to exploratory drilling operations.

DESCRIPTION: Samples of surficial, subsurficial, and suspended sediment collected at regional and site-specific stations were subjected to textural and chemical analyses. A total of 18 regional stations (established to evaluate changes across the entire region) and 29 site-specific stations (located near exploratory rigs) were sampled. The first sampling cruise was prior to drilling in July 1981. Subsequent cruises were conducted seasonally over a three year period. Station location and positioning was achieved using Loran-C. Samples were collected and handled with care to minimize systematic contamination errors. Sediment samples were collected using a 0.1-m² stainless steel Van Veen grab sampler; samples for chemical analyses were taken with noncontaminated utensils, placed in acid-washed polyethylene containers, and frozen until analyzed. Sediment cores were collected during this study using hydraulically damped gravity cores with thin-walled, fiberglass-core barrels and frozen. In the laboratory, samples were thawed, homogenized, and

subsampled under a particle-free hood. Aliquots from individual grabs were separated for chemical and textural analyses. These samples were dried, then particles larger than 2 mm were removed. Drill cuttings were not removed. Further grain-size analyses were performed using a Rapid Sediment Analyzer for sand, and gravimetric techniques for silts and clays. Size distribution of silts and clays was determined with a Coulter particle counter and expressed in phi units.

Trace metal analyses were conducted for aluminum (Al), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), vanadium (V), and zinc (Zn) using several methods. Al, Cr, Fe, Ni, and V concentrations were determined by inductively coupled plasma spectrometry. Cd, Cu, and Pb concentrations were determined using a graphite-furnace atomic absorption spectrophotometer. Results from Ba and Cr analyses were cross checked by an energy dispersive x-ray fluorescence technique. This method was used to analyze all Ba concentrations exceeding 500 ppm.

SIGNIFICANT CONCLUSIONS: Barite (barium sulfate) increased by a factor of 5.9 in bulk sediments 200 m from the drillsite in Block 410 as a result of drilling. Maximum Ba concentrations reached 172 ppm at this site. Because the Ba was in the form of barite, a low toxicity form, no adverse chemical stress to benthic organisms was expected. Of the barite discharged into the waters of Block 312, an estimated 21 to 31% was present in the sediments within 6 km of the drillsite. Projections indicated that sediment Ba levels within 6 km of the drillsite in Block 312 will return to within 10% of pre-drilling levels in 1.5 years. Barite was found in fine sediments as far as 65 km west of the drilling operations. Enriched Ba concentrations are restricted to the upper 2 cm of the sediment, and any residual Ba will be mixed deeper into the sediment column by physical and biological processes.

STUDY RESULTS: Sediments on Georges Bank were comprised mostly of medium to coarse grained, quartzose sand with lesser amounts of gravel, silts, and clays. Silt and clay concentrations were generally less than 4% in regional samples. Significant concentrations of fine sediments detected at regional stations included: the Gulf of Maine (80 to 90% fines); the head of Lydonia Canyon (25 to 30% fines); and the Mud Patch region south of Nantucket Island (92 to 97% fines). Drill cuttings were found in gravel fractions from drillsites in Blocks 312 and 410; some cuttings were found 2 km from the drillsite in Block 410 and within 500 m of the drillsite in Block 312.

Trace metal concentrations, when compared with pre-drilling levels, did not change appreciably. Concentration of Ba in bulk sediments upstream from drilling operations did not increase; this finding held for the other trace metals examined. Chromium concentration in these same samples did not increase as a result of drilling even at the drillsites. In Block 410, however, there were some changes in Ba concentration following drilling operations. Concentrations of Ba 200 m west of the drillsite increased during drilling operations. As expected from prevailing current regimes (east to west), most drilling fluid discharges were transported to the west. Within the fine sediment fractions, barium concentrations increased greatly and reached 8,000 to 10,000 ppm. The net transport of barium-rich fine sediment was to the west. Aluminum, chromium, copper, and mercury in fine sediments increased slightly at one near-rig station in response to drilling but returned to background levels when drilling operations ceased.

Trace metal concentrations in sediment-trap material collected at the head of Lydonia Canyon from April 1981 to November 1982 were very close to pre-drilling concentrations from the same area. Sediment traps located 1 km west of the drillsite in Block 312 revealed higher than pre-drilling Ba

concentrations. Sediment traps located 6 km east of the drilling rig in Block 312 exhibited higher than pre-drilling levels but not as high as the near-rig traps.

Analysis of sediment cores indicated that Ba was the only metal to have a higher concentration in the upper 2 cm of the sediment profile. At least 85% of the drilling-related Ba was in the 0 to 2 cm sediment interval at one station. It was apparent that grab samples containing greater than the top 2 cm may be diluted with uncontaminated sediment from within the sediment profile.

The total inventory of drilling-related barite between 6 and 65 km from Block 312 was estimated at 6.1 million lbs. An estimated total of 9.8 million lbs was discharged to the ocean on Georges Bank during the drilling of eight wells. Approximately 69% of this can be accounted for in the sediment adjacent to drilling rigs.

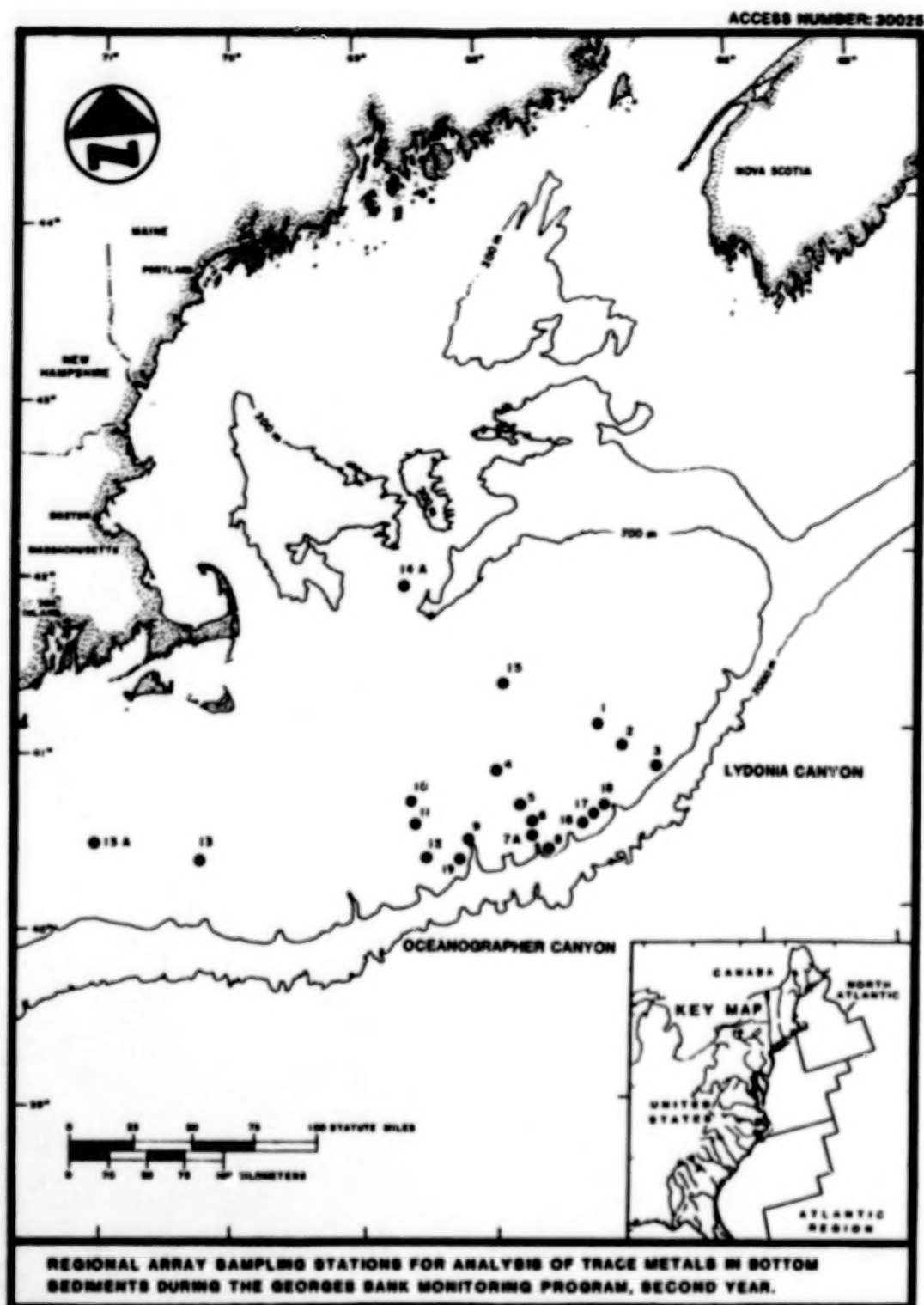
STUDY PRODUCT(S): Bothner, M. H., R. R. Rendigs, E. Campbell, M. W. Doughten, C. M. Parmenter, M. J. Pickering, R. G. Johnson, and J. R. Gillison. 1983. The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Second Year of Monitoring. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84169465. Contract No. 14-12-0001-30025. 88 pp.

Other publications resulting from this work effort include:

Bothner, M. H. 1984. Environmental monitoring in Georges Bank: Trace-metal analysis of bottom sediment, pp. 81-89. In: S. H. Clarke (ed.), Highlights in Marine Research. U.S. Geological Survey Circular 938.

Bothner, M. H., R. R. Rendigs, E. Campbell, M. W. Doughten, C. M. Parmenter, M. J. Pickering, R. G. Johnson, and J. R. Gillison. 1983. The Georges Bank Monitoring Program 1984: Analysis of trace metals in bottom sediments during the second year of monitoring. U.S. Geological Survey Circular 936. 54 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Third Year Monitoring Period.

REPORT TITLE: The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Third Year of Monitoring.

CONTRACT NUMBER(S): MMS: 14-12-0001-30153.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1984.

COMPLETION DATE OF REPORT: February 1985.

COST(S): FY 1984: \$263,824; Cumulative Project Cost: \$263,824.

PROJECT MANAGER(S): M. Bothner.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

ADDRESS: Quisset Campus, Woods Hole, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: M. Bothner.

KEY WORDS: North Atlantic; Georges Bank; Gulf of Maine; Lydonia Canyon; fates and effects; trace metals; sediment; monitoring; exploratory drilling; benthos; grain size; transport; resuspension; drilling discharges.

BACKGROUND: The Georges Bank Monitoring Program was established to measure changes in background levels of contaminants in sediments and organisms associated with exploratory drilling on Georges Bank. This report, prepared by the U.S. Geological Survey, details information on trace metal content of sediments before, during, and after exploratory drilling on Georges Bank.

OBJECTIVES: (1) To ascertain where drilling muds accumulate on Georges Bank; (2) To determine the extent to which trace metals accumulate on Georges Bank; and (3) To determine the duration of elevated trace metal concentrations following cessation of drilling operations.

DESCRIPTION: The monitoring program was conducted to provide data before, during, and after drilling operations which included eight exploratory wells. Samples of surficial, subsurficial, and suspended sediment were subjected to textural and chemical analyses. The first collection cruise was prior to drilling in July 1981. Subsequent cruises were conducted on a seasonal basis over a three-year period. A total of 18 regional stations were established to evaluate changes across the entire region. Twenty-nine site-specific stations (located near exploratory rigs) were also sampled. Station location and positioning was accomplished using Loran-C. Sediment samples were collected with a 0.1-m² stainless steel Van Veen grab sampler. Samples for chemical analyses were taken with noncontaminated utensils, placed in acid-washed polyethylene containers, and frozen until analyzed. Sediment cores collected using hydraulically damped gravity cores were collected in thin-walled, fiberglass-core barrels then frozen. Sediment traps were deployed at various heights above the seafloor in Block 312 and in Lydonia Canyon. In the laboratory, samples were thawed,

homogenized, and subsampled under laminar flow hoods. Samples for chemical analyses were dried to a constant weight at 70°C in a Teflon-coated oven with filtered nitrogen atmosphere. Sand and coarse materials were removed while silt and clay fractions were filtered through a 60-mm screen. Textural analyses were performed on these samples using a Rapid Sediment Analyzer (for sand and shell) and gravimetric methods (for silts and clays). Trace metals were analyzed using various techniques and instrumentation. Aluminum (Al), barium (Ba), iron (Fe), and manganese (Mn) concentrations were determined by inductively coupled plasma spectrometry. Cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), and vanadium (V) concentrations were determined using graphite-furnace atomic absorption spectrophotometry. Zinc (Zn) was determined by induction furnace atomic absorption spectrometry. Mercury (Hg) was determined using induction furnace atomic absorption. Results of Ba and Cr analyses from selected samples were confirmed using an energy dispersive x-ray fluorescence technique. Stock solutions were used to calibrate the analytical instruments.

SIGNIFICANT CONCLUSIONS: The only trace element of the twelve examined that increased in concentration during exploratory drilling on Georges Bank from July 1981 to September 1982 was Ba. The greatest post-drilling Ba concentration reached 172 ppm in sediments near Block 410. This concentration was 5.9 times greater than pre-drilling levels. No changes in the concentrations of the 11 other metals were observed. It was estimated that 25% of the discharged Ba was present in the sediments within 6 km of the rig in Block 312; Ba levels decreased rapidly during the first post-drilling year. Most discharged Ba is associated with the fine fraction of sediment and is distributed widely across the Bank. Evidence of Ba transport was found 115 km west and 35 km east of drilling activities. Resuspension can occur at least 25 m above the sea floor.

STUDY RESULTS: Sediment texture, defined by mean phi values, displayed low temporal variability. Within station variability was less than between station variability. The sediments on Georges Bank are typically greater than 95% sand with gravel, silts, and clays comprising the remaining 5%. Mineral composition of the sand fraction is primarily quartz with minor amounts of feldspar and trace amounts of heavy minerals. Regional stations at which significant concentrations of fine sediments were detected included: the Gulf of Maine (80 to 90% fines); the head of Lydonia Canyon (22 to 30% fines); and the Mud Patch region south of Nantucket Island (92 to 97% fines). Drill cuttings were found in gravel fractions from drillsites in Blocks 312 and 410; some cuttings were found 2 km from the drillsite in Block 410 and within 500 m of the drillsite in Block 312.

Pre-drilling concentrations of trace metals in bulk (unfractionated) sediments seemed to be at natural levels based on geological data from Georges Bank. During the three-year monitoring period, Ba levels in sediments at upstream control stations did not change appreciably while Ba levels at downstream stations exhibited measurable changes. As expected from prevailing current regimes (east to west), most drilling fluid discharges were transported to the west. At one station located 200 m from the drilling rig in Block 410, mean Ba concentrations increased from 32 ppm to 172 ppm. Concentrations of chromium in these same samples did not increase as a result of drilling even at the drillsites. Within the fine fraction of sediment, Ba concentrations increased greatly and reached 8,000 to 10,000 ppm. There were slight increases in Al, Cr, Cu, and Hg in fine sediments at one station in response to drilling, but concentrations returned to background levels when drilling operations ceased.

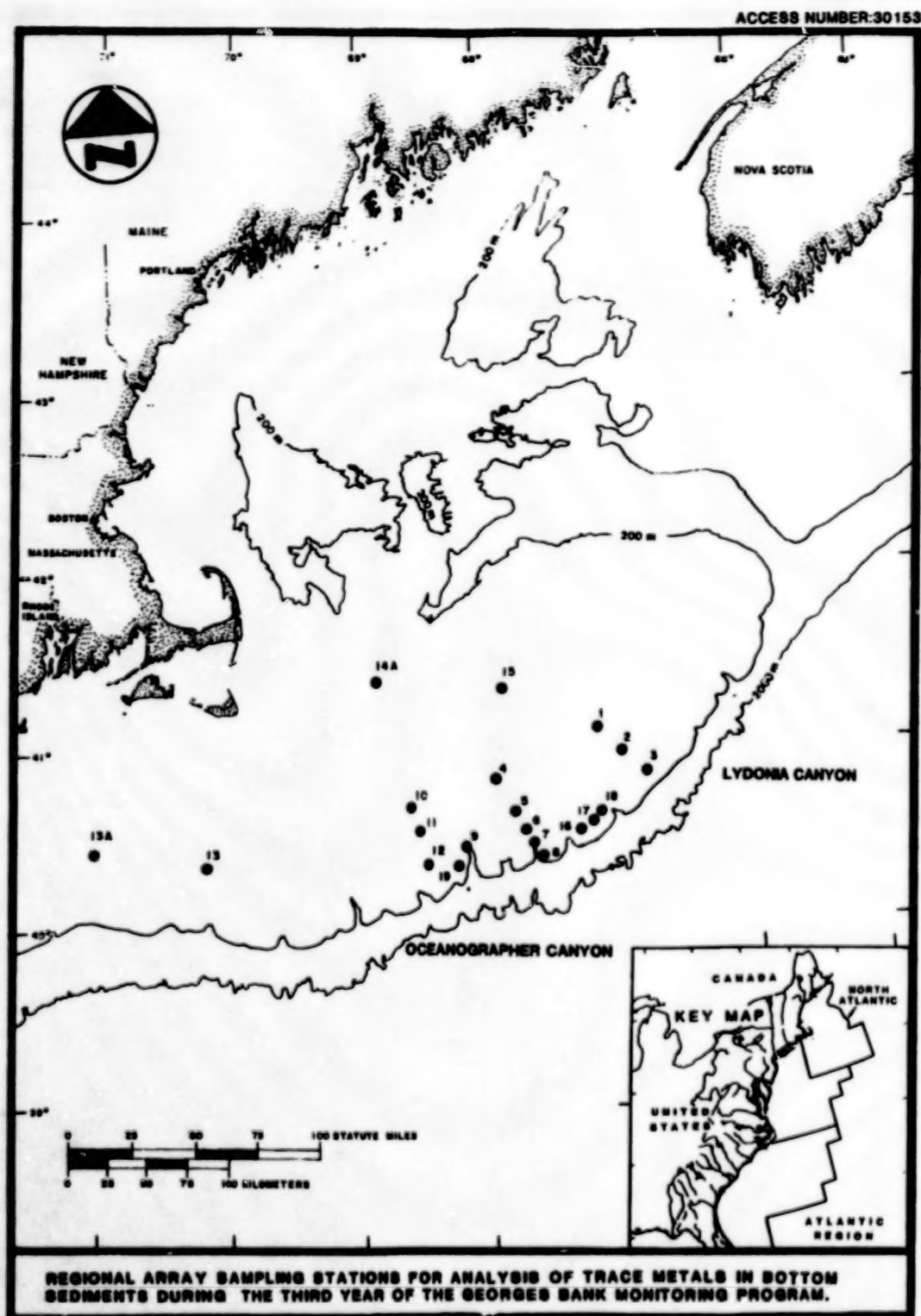
Sediment trap samples had significantly higher concentrations of Ba in post-drilling samples than in pre-drilling samples. One trap sample collected 1 km to the west of the drillsite in Block 312

contained Ba concentrations 5 times higher than pre-drilling concentrations. The findings demonstrated that sediments were periodically resuspended to at least 25 m above the sea floor. Sediment traps located 6 km from a drillsite exhibited higher Ba concentrations in post-drilling samples. Slight indications of drilling mud were present in Lydonia Canyon sediment trap samples.

Analyses of trace metal distribution with sediment depth revealed that Ba and Ba/Al ratios were enriched in the upper 8 cm when compared to deeper sections of the sediment core samples. Other sites displayed subsurface maxima of Ba suggesting that new sediments have been accumulating on top of drilling mud components or that new sediments have been exchanged for the drilling mud components by a combination of sedimentation, sediment mixing, and erosion.

STUDY PRODUCT(S): Bothner, M. H., R. R. Rendigs, E. Y. Campbell, M. W. Doughten, C. M. Parmenter, C. H. O'Dell, G. P. DiLisio, R. G. Johnson, J. R. Gillison, and N. Rait. 1985. The Georges Bank Monitoring Program: Analysis of Trace Metals in Bottom Sediments During the Third Year of Monitoring. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-30153. 99 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



V

GEOLOGY

Geology studies examine the specific features of the Outer Continental Shelf which present an obstacle to oil and gas operations. These features include geohazards, sea ice hazards, and permafrost hazards.

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STUDY TITLE: North Atlantic Geological Studies - First Year.

REPORT TITLE: Environmental Geologic Studies in the Georges Bank Area, United States
Northeastern Atlantic Outer Continental Shelf, 1975-1977. Summary and Final
Report.

CONTRACT NUMBER(S): BLM: MU6-29.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1976; 1977.

COMPLETION DATE OF REPORT: 1980.

COST(S): FY 1976: \$1,660,011; FY 1977: \$236,464; Cumulative Project Cost: \$1,896,475.

PROJECT MANAGER(S): D. Folger.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

ADDRESS: Quisset Campus, Woods Hole, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: J. Aaron, M. Bothner, D. Folger, J. Milliman (WHOI), C. Parmenter,
K. Scanlon, R. Sylwester, D. Twichel.

KEY WORDS: North Atlantic; Georges Bank; hazards; geology; shelf; slope; sediment; suspended
matter; trace metals; transport; seston; submersible.

BACKGROUND: Georges Bank is an OCS area that has been targeted for petroleum exploration and development. Effects of these activities on marine, coastal, and social environments are important considerations in leasing decisions. The U.S. Department of the Interior (USDOI) relies on accurate environmental characterizations when making such decisions. In 1975, the U.S. Geological Survey initiated studies, contracted by the USDOI, to provide basic geologic and oceanographic environmental data from the Georges Bank region. These studies focused on circulation dynamics, sediment mobility, seston dynamics, age of surficial sediments, and shallow structure of the continental shelf and slope off New England.

OBJECTIVES: (1) To measure sediment mobility rates and how they affect bottom morphology and texture; (2) To determine concentrations and dynamics of suspended matter in the water column; (3) To determine vertical distributions of trace metals in near-surface sediments at selected sites; (4) To assess potential hazards to oil and gas activities due to surficial and intermediate depth structure and mass sediment transport events; and (5) To support activities of prime physical oceanography and chemical/biological benchmark contractors by providing and interpreting geological data on physical, biological, and chemical shelf processes.

DESCRIPTION: Three seston samples (surface, mid-depth, and 1 to 2 m above bottom) were collected at 348 stations. Subsamples of each sample were filtered through preweighed millipore (0.45 μ m) filters, rinsed, and frozen. In the laboratory, filters were split, then one half was ashed at 500°C to determine the combustible fraction, and the other half examined for elemental composition using scanning electron and petrographic microscopy. Sediment sampling employed vibracores (for depths to 6 m) and hydraulically damped gravity cores (for depths to 70 cm).

Twenty-one vibracore samples were cut into 150-cm sections and stored at 3°C. Thirty-five hydraulically damped gravity cores were frozen in upright position. In the laboratory, subsamples of split cores were subjected to textural analyses (sieve, settling tube, and pipette), clay mineralogy (X-ray diffraction), trace metal analysis (acid leaching technique) and radio carbon analysis (carbon analyzer). Submersible dives were conducted at five sites in the Georges Bank region: one on the northwestern flank, two on the southeastern flank, and two in Great South Channel. Photographs were taken with hand-held 35-mm cameras and a TV camera. Temperature, transmissivity, seston and grab samples were taken during each dive. A seismic survey, covering 2,900 km of the bank, was conducted using a Del Norte 800 joule minisparker and a 200-element hydrophone. Reflected signals were filtered between 200 and 1,000 Hz.

SIGNIFICANT CONCLUSIONS: Circulation dynamics on Georges Bank promote considerable sediment transport which could threaten stability of support structures associated with the seafloor. Spatial variability in textural components of shallow buried sediments was significant. When sediments are loaded, differential settling may present stability problems for structures placed upon them. An area of seafloor, covered by mud, lying southwest of Georges Bank might act as a sink for contaminants such as hydrocarbons and trace metals. A conspicuous layer of suspended material sometimes present in the water column on the south flank of the bank might interact with and subsequently disperse or settle pollutants.

STUDY RESULTS: Concentrations of suspended matter from shelf and slope waters range from 50 to 15,000 μ g l⁻¹. The high value is significant as it exceeds estimated levels (3,000 to 5,000 μ g l⁻¹) that may cause crude oil to sink to the bottom. Suspended material in surface waters is from biogenic (combustible) or lithogenic (non-combustible) sources. Seasonal variation in water column stability, temperature, and biological productivity determine whether biogenic or lithogenic material will predominate. The influence of major storms will override at any season. High concentrations of lithogenic material were found in bottom waters west of the Great South Channel and southwest of Nantucket Island. The seafloor at the latter site is covered with silty clay up to 6 m thick. Whether this mud patch is a sediment source or sediment sink is in question. Initial age estimates using C¹⁴ and Pb²¹⁰ suggest that the mud area is a sediment sink. Therefore, this area may represent a major depositional site for pollutants.

The dominant size class of sediments at all depths on Georges Bank was sand. Gravel was common and represented up to 35% of the sediment in some core horizons. Coarse-grained sediments in the cores were low in organic carbon ($x = 0.08 \pm 0.05\%$). Silts and clays were found mostly in samples west of the Great South Channel. The major clay mineral was illite, with chlorite and kaolinite present in moderate amounts. No depth related variation was noted for the clay-mineral assemblage. Concentrations of trace metals (barium, cadmium, chromium, copper, iron, lead, nickel, vanadium, and zinc) were low and typical of unpolluted coarse grained sediments. Vertical distributions of chromium and zinc were correlated to percentages of clay and silt in some cores. These observations were attributed to natural variability in grain size and organic carbon

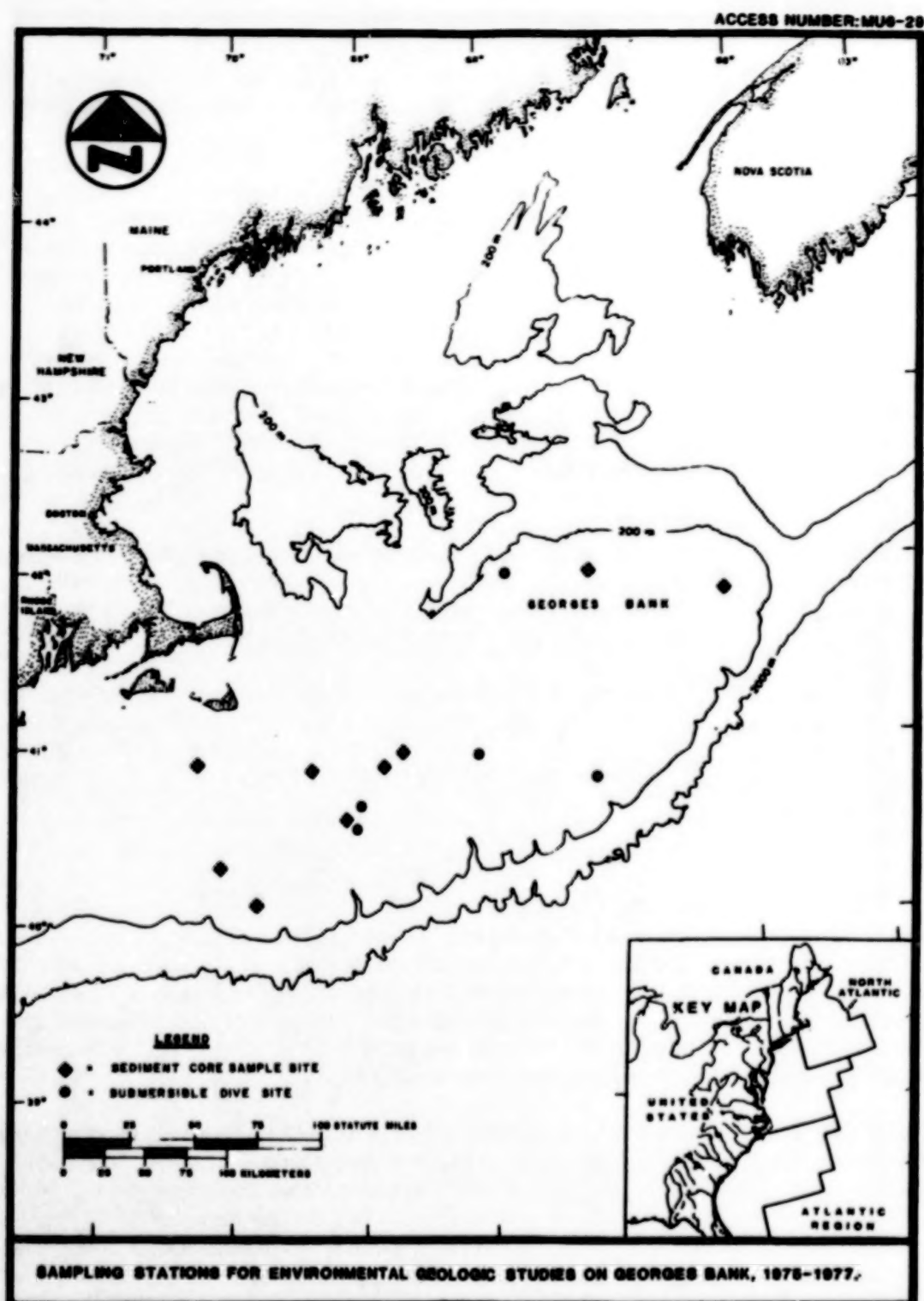
content. Near-surface sediments from the area south of Nantucket and Martha's Vineyard were significantly younger than near-surface sediments in other cores analyzed. Thus, active accumulation of sediments is taking place in this area. The source of these fine sediments is possibly the area of coarse-grained sediments on Georges Bank and Nantucket Shoals. Fine sediment washed from those areas may be transported southwestward toward the "mud patch" by net current drift. Again, this mud patch area could become a sink for pollutants with affinities for fine grained sediment.

Submersible observations provided important visual data from the water column and seafloor. The water column over Georges Bank was well mixed with no definite thermocline. Turbidity was generally high, except near the bottom. Transmissometer-nephelometer readings revealed a prominent layer of suspended matter between 40 and 55 m on the south flank of the bank. Seafloor observations indicated that tidal currents caused considerable resuspension and transport of sediment in Great South Channel and where water depths were less than 50 m. Wave-induced and wind-driven currents associated with storm systems would also cause sediment transport. Sediment and circulation dynamics of this nature would create potential hazards for petroleum exploration structures. Seismic-reflection data showed that the parameters of shallow sediments on Georges Bank were quite variable and changed dramatically over short distances. Sediments with such variable properties could settle differentially when loaded and thus could pose potential hazard to large structures erected on them.

STUDY PRODUCT(S): Aaron, J. M. (ed). 1980. Environmental Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Outer Continental Shelf, 1975-1977. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB80177512. Contract No. AA550-MU6-29. 188 pp.

Aaron, J. M. (ed.). 1980. A Summary of Environmental Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Outer Continental Shelf, 1975-1977. An Executive Summary of the final report by the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB80177520. Contract No. AA550-MU6-29. 22 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic OCS Geological Studies/Georgia Embayment Region.

REPORT TITLE: South Atlantic Outer Continental Shelf Geological Studies, Fiscal Year 1976.
Executive Summary Report; Geology (Final Report).

CONTRACT NUMBER(S): BLM: MU6-56.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1976; 1977.

COMPLETION DATE OF REPORT: July 1979.

COST(S): FY 1976: \$330,500; FY 1977: \$821,532; Cumulative Project Cost: \$1,152,032.

PROJECT MANAGER(S): M. Ball, D. Folger, P. Popenoe.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

ADDRESS: Quisett Campus, Woods Hole, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: M. Ball, M. Bothner, B. Butman, L. Doyle, D. Edsall, V. Henry, C. Paul, O. Pilkey, P. Popenoe.

KEY WORDS: South Atlantic; Georgia Embayment; Florida; Georgia; South Carolina; North Carolina; geology; hazards; shelf; sediment; trace metals; suspended matter; transport; geophysical; currents; slope; hard bottom; Gulf Stream; Blake Plateau.

BACKGROUND: The U.S. Department of the Interior, through a series of meetings with State, Federal, and academic representatives, developed a studies program in chemical, biological, physical, and geological oceanography of the South Atlantic Outer Continental Shelf (OCS). A variety of geological studies were conducted to assess conditions and hazards that might cause or distribute oil spills or pollutants, or constrain petroleum exploration or development of the area.

OBJECTIVES: (1) To measure the rate, direction, and forcing mechanisms of sediment mobility over the seabed, and to monitor resultant changes in bottom morphology or texture; (2) To determine the concentration, distribution, and flux of suspended particulate matter in the water column; (3) To determine the vertical distribution of trace metals in the near-surface sediment at selected locations; (4) To evaluate potential geological hazards to oil and gas development due to surficial and intermediate depth structure and mass transport events; and (5) To identify and evaluate the distribution and significance of outcrop and reefal structures.

DESCRIPTION: Seven cruises were conducted from 1975 to 1977 to generate seismic profiles, collect sediments and seawater, and deploy and recover instrumented tripods. Suspended sediments were sampled from a grid of 50 stations on seven transects across the OCS between Cape Canaveral, Florida and Cape Fear, North Carolina. Two depths were sampled at shallow stations and three at deeper stations using 30-l Niskin bottles. Total suspended solids were collected on 47 mm, 0.4 um pore size Nuclepore filters, processed and refrigerated on board ship. Transmissometer depth profiles also were made at each station. An instrumented tripod array

Access Number: MU6-56

equipped with sensors for current, pressure, temperature, light transmission, and bottom photography was placed at a single station. Vibracore samples were x-rayed in their liners, then split in half. One half was subsampled to determine percent carbonate, percent organic carbon, clay mineralogy, light mineralogy, heavy mineralogy, and sediment texture. Radiocarbon dating was also performed. High-resolution seismic reflection profiles were obtained along cross-shelf transects using a 3.5 kHz echo sounder, miniparker (600 joule), and airguns (160, 80, 40, and 20 in.³). Seismic gear coupled with side-scan sonar were used to map the distribution of hard-bottom areas along several cross-shelf transects. Sediment samples for trace metals analyses were collected using vibracores and a hydraulically-damped gravity corer. Samples were completely dissolved and analyzed for the total content of chromium (Cr), copper (Cu), and zinc (Zn) as well as aluminum (Al), barium (Ba), cadmium (Cd), iron (Fe), lead (Pb), manganese (Mn), molybdenum (Mo), nickel (Ni), and vanadium (V). After partial leaching, samples were analyzed using atomic absorption or spectrophotometric methods.

SIGNIFICANT CONCLUSIONS: Surficial sediments, bottom currents, and suspended sediments within the water column were related to surface and internal waves, tides, storm-driven currents, and the Gulf Stream. Trace metals levels were indicative of uncontaminated conditions throughout the surficial sedimentary layer. Hard-bottom areas on the South Atlantic OCS were infrequent and found mostly offshore of Florida, South Carolina, and North Carolina. With proper precautions, only strong currents of the Gulf Stream will present a major hazard to exploration or development on the continental margin. Proper rig placement and engineering will overcome any geohazards present in the study area.

STUDY RESULTS: Suspended sediment load was highest at inshore stations due to finer grain-size materials and the input of silt and clay particles from river systems. Seasonally, total suspended sediment load was highest in winter, slightly lower during summer, and considerably lower during spring and fall. The most abundant minerals in suspension were feldspar and quartz followed by kaolinite.

The average near-bottom current speed from the tidal cycle was 19 cm sec^{-1} with speeds in excess of 30 cm sec^{-1} recorded about 10% of the time. Tidal cycle transport of suspended particles was estimated at 4 km across and 1 km longshelf during each cycle. Long-term currents from atmospheric forcing or Gulf Stream intrusions averaged less than 10 cm sec^{-1} . The mean flow over the entire current record was 1.3 cm sec^{-1} . Observations revealed that the upper 5 to 10 cm of surficial sediments were consistently reworked by bottom currents and benthic organisms. Little bottom resuspension or long distance transport of bottom sediments occurs in the mid-shelf area. Nearshore and on the slope, sediment grain size tends to be in the fine sand range, whereas on the central and outer shelf, grain size was in the medium to coarse range. Lithofacies of the shelf were mapped, indicating that fine terrigenous sands predominate north of Cape Hatteras. Calcareous and terrigenous sands were present between Cape Hatteras and Cape Romain. Sediments in Onslow Bay and offshore of Florida are mostly calcareous sand. Terrigenous sands predominated south of Cape Romain off Georgia and South Carolina. In general, sediments of the shelf were Holocene-Pleistocene, usually under 4 m and rarely over 6 m thick. Sediment trace metals levels in all cores analyzed were uniform with sediment depth and low with respect to average crustal abundance. Concentrations were typical of uncontaminated coarse-grained sediments, and exhibited no evidence of anthropogenic contamination.

Three general types of hard bottom were identified using seismic reflection and side-scan sonar. The most common were low relief areas covered by a thin sand veneer. Moderate relief areas were less common on the shelf. These areas supported various epibiota and had relief of 2 m or less. High relief outcrops occurred in discontinuous ridges along the OCS in water depths ranging from 20 to 110 m. These areas supported abundant epibiotical and fish assemblages.

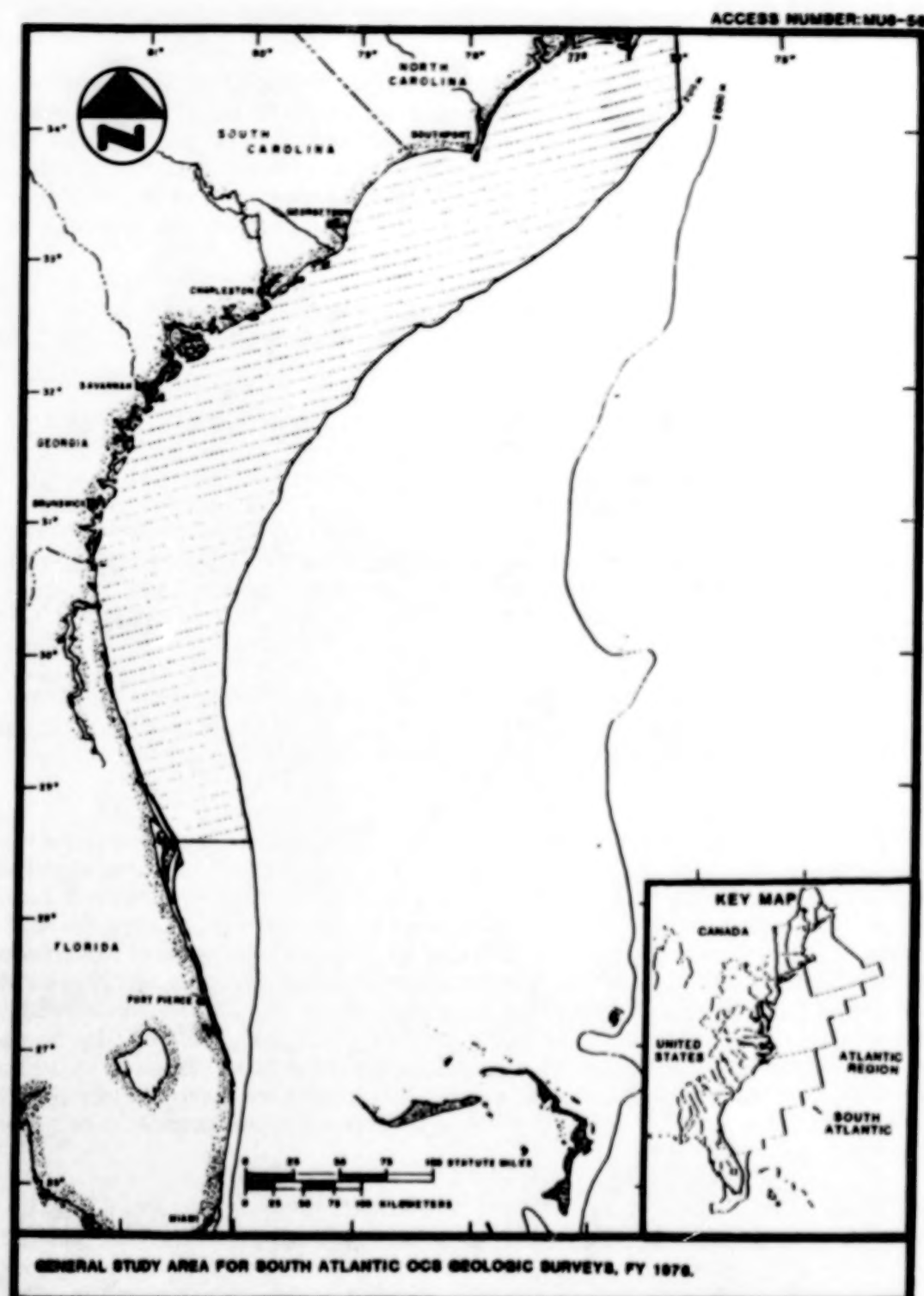
Seismic reflection profiles revealed several stratigraphic layers on the shelf. Three units of the upper Cretaceous were seismically distinguished; these were overlain by flat-lying Paleocene age strata. The upper sequence was thin and exhibited a complex history of erosion, possibly due to the Gulf Stream. The Gulf Stream controlled sedimentation on the Blake Plateau throughout the Tertiary. Eocene, Oligocene, and Miocene beds form a progradational sequence over the Paleocene layer west of the present Gulf Stream. Some evidence of an offshore freshwater aquifer was found off Florida.

Geologic hazards discovered and mapped included sand waves, submarine cut and fill, scour or steep topography, faults, slump masses, water column anomalies, shelf-edge reefs, and deepwater reefs.

STUDY PRODUCT(S): U.S. Geological Survey. 1979. South Atlantic Outer Continental Shelf Geological Studies, Fiscal Year 1976. Executive Summary Report. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB-300822. Contract No. AA550-MU6-56. 40 pp.

U.S. Geological Survey. 1979. South Atlantic Outer Continental Shelf Geological Studies, Fiscal Year 1976. Geology. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB-300820. Contract No. AA550-MU6-56. 562 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic OCS Geologic Studies, FY 1978.

REPORT TITLE: Environmental Geologic Studies on the Southeastern Atlantic Outer Continental Shelf, 1977-1978.

CONTRACT NUMBER(S): BLM: MU8-13.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978.

COMPLETION DATE OF REPORT: 1981.

COST(S): FY 1978: \$984,598; Cumulative Project Cost: \$984,598.

PROJECT MANAGER(S): P. Popenoe.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

ADDRESS: Quisset Campus, Woods Hole, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: P. Popenoe.

KEY WORDS: South Atlantic; Blake Plateau; hazards; geology; transport; sediment; pollutants; trace metals; suspended matter; particulates; shelf; slope; spectrophotometry; hard-bottom; Florida Current.

BACKGROUND: The U.S. Department of the Interior began geological studies of the Outer Continental Shelf (OCS) and slope areas off the southeastern United States in 1978. These surveys were to provide geological hazard assessments and overall environmental characterizations necessary for proper management of OCS lands preceding oil and gas exploration. This report complements environmental geologic information obtained for Mid-Atlantic and North Atlantic OCS regions.

OBJECTIVES: (1) To determine the sedimentation rates and processes on the upper slope and inner Blake Plateau; (2) To determine the distribution, areal extent, and vertical characteristics of geological features supportive of biological communities; (3) To monitor the transport of bottom sediment across the OCS, to evaluate its possible effect on pollutant transfer along the seabed and the potential of the sediment as a pollutant sink, to determine the implications of erosion/deposition on pipeline placement, and to aid in the interpretation of chemical, biological, and physical data; (4) To determine the concentration levels of chosen trace metals and silica in three chemically defined fractions of suspended particulate matter (seston); (5) To study the shelf edge and slope near areas of oil and gas interest, and the northern portion of the Blake Plateau for evidence of slope instability and other geologic hazards; and (6) To determine the depth and rate of sediment mixing caused by large storms and/or by benthic organisms and where possible to estimate the rate of sediment accumulation.

DESCRIPTION: Eleven cruises were made from 1978 to 1979 to obtain field data necessary to describe this region geologically. Suspended particulate matter samples previously collected during

1977 were analyzed for organic content and trace metal concentration. Atomic absorption spectrophotometry was used to determine trace metal (aluminum, cadmium, copper, iron, and lead) concentrations. Sediment samples were taken with hydraulically damped gravity cores, piston cores, and Smith-McIntyre grabs. Gravity cores collected during 1978 were subjected to geochemical (lead isotope) analyses. Piston core and grab samples collected from the continental slope between the shelf break and the Blake Plateau were x-rayed, split, and described. Subsamples of these splits were analyzed for texture, percent calcium carbonate, total organic carbon, and clay mineralogy. Forty-two piston cores collected along transects perpendicular to depth contours were analyzed for sediment composition and texture. Coral and foraminiferan sands extracted from these samples were aged using radiocarbon methods. Carbonate analysis, using an acid leaching technique, was performed on dried splits. Four cruises from July 1977 through May 1978 were conducted to establish the occurrence and distribution of live-bottom areas and shallow geologic hazards (channels, faults, scours) on the South Atlantic OCS. These investigations were completed using subbottom profilers, side-scan sonar, and towed underwater television camera. Deep seismic reflection profiles were made along 14 east-west tracklines spaced 30 km apart and connected to two north-south tie lines. Profiles were recorded between 28 and 32°N Lat on the Blake Plateau using air gun (40 in³), sparker unit (600 joule), and echosounder (3.5 kHz). Signals from these instruments were gathered by a 200-element hydrophone cable, then filtered at 150/300 Hz (air gun) and 65/150 Hz (sparker), and recorded on magnetic tape. Loran-C and satellite navigation were used for positioning and navigation.

SIGNIFICANT CONCLUSIONS: Total suspended load (amorphous silicates, aluminum silicates, and trace metals) increased in a seaward direction while carbonate and organic content exhibited a reverse trend. The Florida Current was responsible for sediment transport and resuspension, especially on the outer shelf. On the slope at Cape Hatteras, sand and calcium carbonate fractions increased relative to the north, revealing a sedimentological break. The continental slope was an area of deposition relative to the adjacent shelf. Significant bed load spillover across the shelf suggested that the slope was a potential sink for pollutants. Geologic hazards, though considered minor, included carbonate features, Florida Current effects, and frozen gas hydrate layers which may trap shallow gas. One slump mass was located on the Florida-Hatteras Slope between the 400- and 500-m isobaths.

STUDY RESULTS: The highest suspended particulate matter values were associated with low salinity waters (33 ppt). Total suspended loads were highest during winter (1.77×10^8 MT), slightly lower during spring (1.73×10^8 MT), and considerably lower during summer (0.82×10^8 MT) and fall (0.72×10^8 MT). Calcium carbonate percentages were lowest inshore and higher near Florida Current waters. Total standing crop of carbonate in the water column was highest in winter (12.0×10^4 MT). Kaolinite and illite dominated the clay mineral suite of suspended sediments, while smectite was more important in shelf and coastal plain sediments. South of Cape Hatteras, calcium carbonate and sand content increased relative to the slope areas to the north. Subbottom profiles and sonograms indicated that the area was covered by a thin veneer of sand. Up to 90% of the inner shelf and as much as 50% of the outer shelf were overlain by this veneer. The thickness of the deposit ranges from 0 to 3 m or more. Underlying sediments were of slightly coarser grain size and higher shell content. This layer was unconsolidated in the upper portion as it supported the formation of small-scale bed forms that migrated as units. Bedforms identified using underwater television were ripples, megaripples, and sand waves. Large sand waves of three different morphologies were recognized; linear parallel with straight crests, rhomboid waves with intersecting crests that formed diamond shaped waves, and irregular waves. Most sand waves were observed

within the 25-m isobath. Other bed bottom features included areas of local scour and bioturbation. A slightly higher density of bioturbation was noted in coarser sediments and near live/hard-bottom areas. Hard-bottom areas were classified as low-relief, moderate-relief (0.5 to 2 m), and high-relief hard bottom. High-relief hard bottoms were associated with the shelf break off Jacksonville, FL; Brunswick, GA; and Charleston, SC. Low-relief bottoms were more frequently encountered and supported diverse epifaunal communities and populations of reef-associated fishes (e.g., angelfishes, groupers, snappers, wrasses). Echinoids, holothuroids, and other burrowing organisms were predominant over level bottoms adjacent to hard-bottom features. Coarse sand bottom comprised of shell hash and algae was also observed on the shelf. Seismic stratigraphy revealed that the Blake Plateau represents the frontal edge of a thick continental margin sedimentary prism. This is a thick Upper Cretaceous unit overlain by a thinner Cenozoic layer. The Cretaceous continental margin was considerably different from that at present. Cenozoic layers, including Paleocene, Miocene, Oligocene, are relatively thin presumably due to scour by incursions of the Florida Current. Shallow acoustic reflectors detected by subbottom profilers included deep and shallow river channels. Shallow channels were most common; the highest density was found in nearshore profiles between Tybee Island to St. Catherine's Island. Shallow reflectors were presumably Pleistocene while deep reflectors were Pliocene. The absence of these features on the outer shelf was due to scour by the Florida Current.

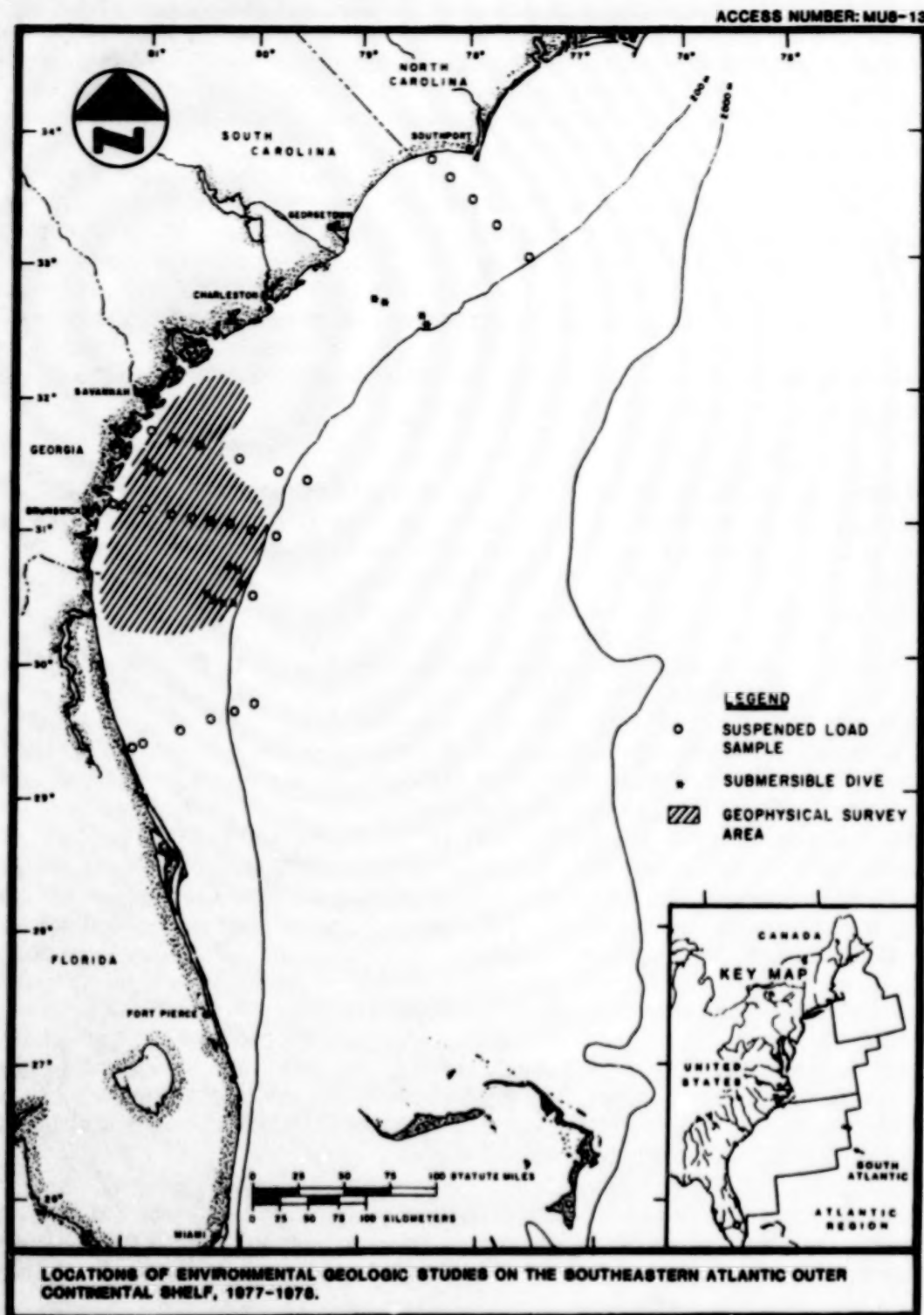
STUDY PRODUCT(S): Popenoe, P. (ed.). 1981. Environmental Geologic Studies on the Southeastern Atlantic Outer Continental Shelf, 1977-1978. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB82-109265. Contract No. AA551-MU8-13. Open File Rept. No. 81-582A and 81-582B. 691 pp., 15 plates and app.

Popenoe, P. 1981. A Summary of Environmental Geologic Studies on the Southeastern United States Atlantic Outer Continental Shelf, 1977-1978. Open File Rept. No. 81-583. 45 pp.

Published proceedings, presentations, or abstracts which resulted from this work effort were associated with the following conferences: (1) Geological Society of America [Bother and Locker (1977); Woo et al. (1978); Pilkey et al. (1979); Behrendt et al. (1980); Pinet and Popenoe (1980, 1981, 1982), Popenoe and Pinet (1980); Pinet et al. (1984); Popenoe and Pinet (1984)]; (2) American Association of Petroleum Geologists, Atlantic Margin Energy Conference, 4-6 October 1981 [Ayers et al. (1981); Foley and Henry (1981); Pinet and Popenoe (1981)]; (3) Tenth Offshore Technology Conference [Folger et al. (1978)]; (4) Second Symposium on the Geology of the Southeastern Coastal Plain, 5-6 March 1979 [Popenoe (1979)].

Journal articles include: Butman and Noble (1978); Doyle and Pilkey, eds. (1979); Doyle et al. (1979); Knebel (1980); Pilkey et al. (1981); Pinet et al. (1981); Pinet and Popenoe (1982); and 2 publications by Pinet and Popenoe (1985). A single Master's Thesis (Foley, 1981, Univ. of Georgia) resulted from this study. Workshop proceedings include Manheim et al. (1982) in Hallback and Winter (eds.) (1982). Open File Reports (Popenoe, 1980) and miscellaneous USGS field investigations (Popenoe et al., 1980; Paul et al., 1980) were also developed.

*PI.'s affiliation may be different than that listed for Project Manager(s).



STUDY TITLE: Studies of the Environmental Geology of the Middle and North Atlantic OCS Region.

REPORT TITLE: Environmental Geologic Studies in the Georges Bank Area, United States
Northeastern Atlantic Continental Margin, 1978-1979. Summary and Final Report.

CONTRACT NUMBER(S): BLM: MU8-24; BLM: MU9-04.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978 (MU8-24); 1979 (MU9-04).

COMPLETION DATE OF REPORT: 1982.

COST(S): FY 1978: \$999,782; FY 1979: \$1,284,140; Cumulative Project Cost: \$2,283,922.

PROJECT MANAGER(S): J. Aaron (MU8-24), J. Robb (MU9-04).

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

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PRINCIPAL INVESTIGATOR(S)*: J. Booth, M. Bothner, B. Butman, M. Noble, D. O'Leary, K. Scanlon, D. Twichell (MU8-24); J. Aaron, R. Beardsley, J. Booth, M. Bothner, B. Butman, J. Hampson, Jr., H. Knebel, J. Moody, M. Noble, D. O'Leary, L. Poppe, D. Twichell (MU9-04).

KEY WORDS: North Atlantic; Mid-Atlantic; hazards; physical oceanography; Georges Bank; sediment; dynamics; suspended matter; Veatch Canyon; Lydonia Canyon; Alvin Canyon; photographs; videotapes; hydrography; transport; isotope; shelf; slope; nutrients.

BACKGROUND: To acquire information that will allow cogent management decisions, the U.S. Department of the Interior funded a three-year survey of oceanographic and geologic features of Georges Bank. This report contains results of the 1978-1979 investigations on circulation patterns, sediment dynamics, and other geological parameters.

OBJECTIVES: (1) To characterize regional circulation patterns and to relate them to sediment dynamics; (2) To determine concentration, distribution, and flux of suspended matter in the water column; (3) To estimate changes in bottom morphology and rates of sediment mobility; (4) To identify and characterize mass movement features; (5) To identify potential hazards in shallow subsurface sediment and to assess the potential for failure under natural or engineered stress; and (6) To assess geotechnical properties of near-subsurface sediment.

DESCRIPTION: Hydrographic data were collected from 66 current meters on 34 moorings, and 26 bottom tripod instrument systems located at 13 stations around Georges Bank. Aircraft-tracked surface drifters, and satellite-tracked drifters were used to estimate surface currents. Moored current meters were positioned for one month to more than a year.

Samples of suspended material were collected from surface, mid-depth, and 1 to 2 m off the bottom at each station. Sediment traps were deployed at two stations, one on Georges Bank and another south of Martha's Vineyard, to measure vertical distribution of suspended matter over a 24-h period.

Subsamples were washed, filtered (Millipore 0.45 μm), and frozen. In the laboratory, subsamples were air-dried, weighted, split, and one half ashed at 500°C to determine the combustible fraction. Portions of the remaining half were examined using scanning electron and petrographic microscopy to identify biogenic and mineralogic composition. Dissolved nutrients (ammonia, nitrate, nitrite, phosphate, and silicate) were analyzed by standard colorimetric methods. Transmissometer readings

were continuously recorded. Radio carbon measurements were performed on total organic content of dried core samples using an acetylene gas counting method. Lead (^{210}Pb) analysis was also performed.

Geophysical data consisted of high resolution seismic reflection profiles, short range (100 m per side) side-scan sonar data, and echo sounder data collected from Georges Bank and the shelf south of Martha's Vineyard. Additional seismic profiling was completed during submersible dives in Veatch and Lydonia Canyons using minisparkers. Eleven piston cores were obtained on the continental slope near Alvin Canyon for geotechnical and interstitial gas evaluations. Geotechnical tests (shear and remolded strength) were performed on core samples using a four-bladed 12.7 mm² vane, inserted 20 mm into the sample then rotated at a rate of 0.0262 radians s⁻¹ (90° min⁻¹). Index properties (bulk density, water content, liquid and plastic limits) were determined by standard procedures. Grain-specific gravity was measured with an air-comparison pycnometer. Consolidated undrained triaxial tests with pore-pressure measurements were performed in three trials: 1, 2, and 4 times the in situ overburden pressure. Eight submersible dives in Veatch and Lydonia Canyons provided additional verbal and photographic (540 35-mm slides, 1.5 h video) documentation of surficial geology and biota along the upper slope of the continental margin.

SIGNIFICANT CONCLUSIONS: Circulation around Georges Bank follows a clockwise pattern with a six-month cycle time, although occasional reversals are possible. Sediment transport on the bank is considerable and under the influence of tidal and storm generated currents. Fine silts and clays are winnowed from the bank and accumulate in the Mud Patch region south of Martha's Vineyard; it was confirmed that this is an area of modern deposition. Continental slope sediments exhibited high shear strengths but were sensitive and would lose their strength if shocked.

STUDY RESULTS: Mean current flow at 45 and 75 m was to the southwest at approximately 8.6 and 3.5 cm s⁻¹, respectively. Seasonal changes of 6 cm s⁻¹ at 45 m and 0 at 75 m were found. Hydrographic observations of perimeter locations suggest a year-round clockwise circulation pattern with flow being strongest in summer and weakest in winter. Tidal currents (50 to 100 cm s⁻¹) on the bank kept the water column well mixed. Low-frequency wind driven currents and shelf waves accounting for 70 to 90% of the energy in along-shelf currents could be attributed to low-frequency wind driven currents. Highest recorded values (>500 $\mu\text{g l}^{-1}$) for suspended matter in surface waters were from Georges Bank. In bottom waters, highest concentrations (5,680 $\mu\text{g l}^{-1}$) were from Hudson Canyon. Organic fractions (combustibles) in surface waters were highest (75 to 90%) near Hudson Canyon while non-combustible material reached high values (60%) at Georges Bank. Geochemical analyses (^{14}C and ^{210}Pb) support the contention that the Mud Patch region is a modern sink for fine grain sediments and sediment related pollutants.

Four bed-form provinces were identified using side-scan sonar and echo sounding techniques: large sand waves, small sand waves, megaripples, and featureless seafloor. The presence of each feature is dependent on the strength of the tidal current regime. Large sand waves are present where surface currents exceed 70 to 80 cm s⁻¹. Bedforms are not found where surface currents are

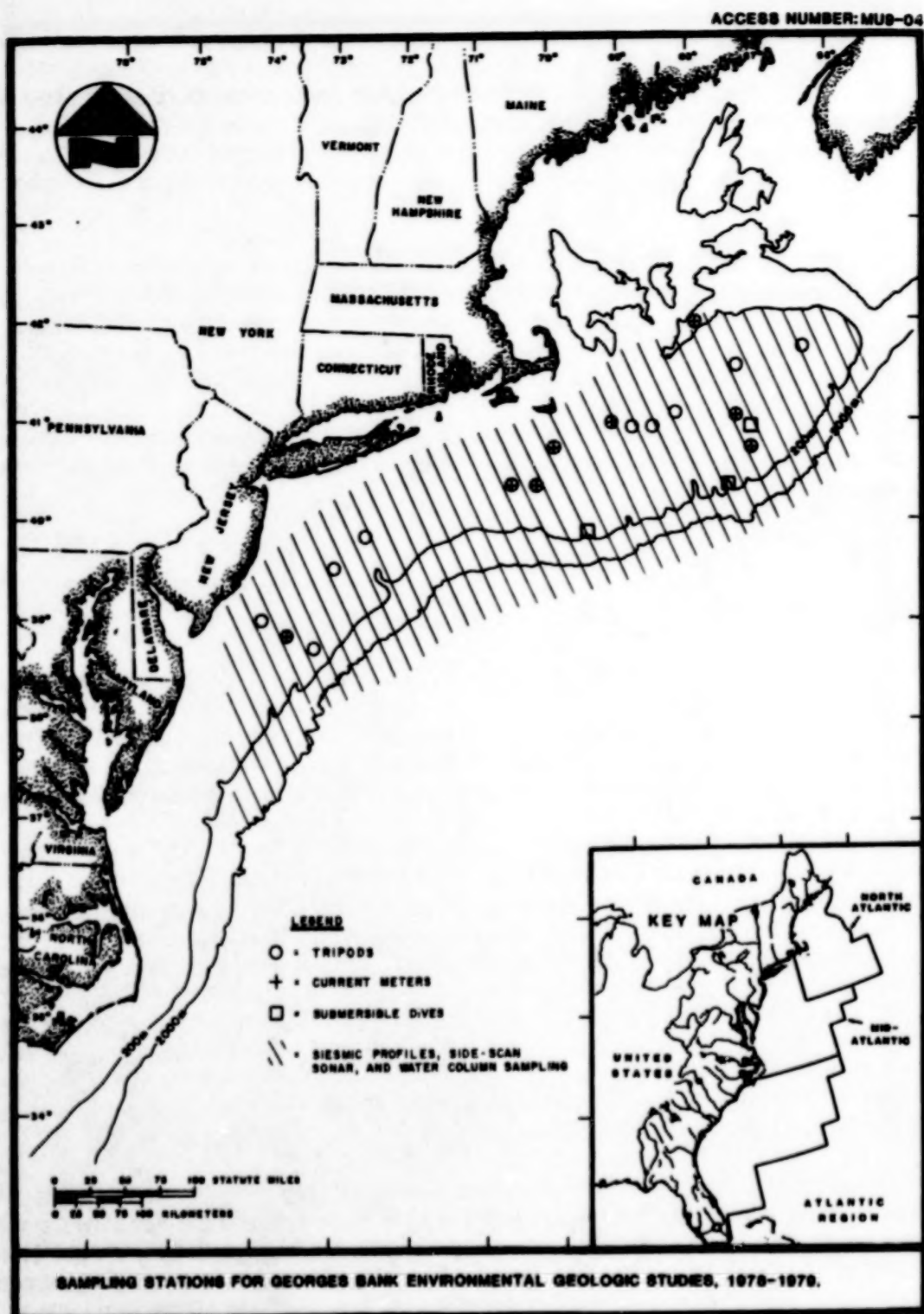
weaker than 40 to 50 cm s⁻¹. Fine sediments (silts and clays) are being winnowed and deposited to the Mud Patch region south of Martha's Vineyard.

Continental slope sediment differed significantly from that of the shelf. Only a thin veneer of surficial sediment is present on the upper slope. This sediment layer is believed to be relict Pleistocene beach or dune sand. Static slope stability analysis indicates previous overburdens at two sites, but potential for mass sediment movement is low; these findings were supported by submersible observations. Subsurface sediments (clay) exhibited high shear strengths but were highly sensitive. This suggests that they would lose strength if shocked. Sediment stability is not likely to be affected by internal gas.

STUDY PRODUCT(S): MU8-24: O'Leary, D. W. (ed.). 1982. Environmental Geologic Studies in the Georges Bank Area, United States Northeastern Atlantic Continental Margin, 1978-1979. A summary and final report by the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB83144808. Contract No. AA551-MU8-24 and AA551-MU9-04. 348 pp.

MU9-04: Robb, J. M. 1982. Environmental Geologic Studies in the Mid-Atlantic Outer Continental Shelf Area. Results of 1978-1979 Field Seasons. Contract No. A551-MU8-24 and A551-MU9-04. NTIS No. PB83147934.

**PI.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Mid-Atlantic Geological Studies - Third Year.

REPORT TITLE: Environmental Geologic Studies in the Mid-Atlantic Outer Continental Shelf Area.
Results of 1978-1979 Field Seasons.

CONTRACT NUMBER(S): BLM: MU8-21; BLM: MU9-04.2

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978 (MU8-21); 1979 (MU9-04).

COMPLETION DATE OF REPORT: 1982.

COST(S): FY 1978: \$848,898; FY 1979: \$1,284,140; Cumulative Project Cost: \$2,133,038.

PROJECT MANAGER(S): J. Robb.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

ADDRESS: Quisett Campus, Woods Hole, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: J. Robb.

KEY WORDS: North Atlantic; Mid-Atlantic; Mid-Atlantic Bight; Georges Bank; hazards; sediment; transport; seasonality; currents; particulates; nutrients; Gulf Stream; shelf; slope.

BACKGROUND: Environmental geologic studies, supported by the U.S. Department of the Interior, have been conducted on the Mid-Atlantic Outer Continental Shelf (OCS) since 1975. A primary goal of these investigations is to provide data concerning potential geologic hazards or environmental parameters that might interact with oil and gas activities on the Mid-Atlantic OCS. This report contains results of sediment, suspended matter, and geophysical studies conducted in this area during 1978 and 1979.

OBJECTIVES: (1) To estimate the extent and rate of sediment mobility over the sea bed and to monitor resultant changes in the bottom morphology and texture; (2) To identify major processes causing sediment movement and to assess seasonal variability; (3) To complete a study of suspended particulate matter; (4) To determine rates and depths of sediment mixing in Sale 40 and 49 lease areas as an aid to predicting the fate of spilled hydrocarbons, drilling muds, and cuttings; (5) To identify and map areas of slumping or potential slumping hazards in lease areas on the continental slope; (6) To identify and study the effects of processes and mechanisms contributing to sediment instability in offshore lease areas which may lead to inception of slumping and sliding; (7) To assess the geotechnical properties of sediments in continental slope lease areas; and (8) To determine potential geologic hazards in nearshore areas.

DESCRIPTION: Current and water column measurements were recorded using moored current meters and instrument packages. Vector averaging current meters were deployed at two stations in 60- and 234-m water depths from August to December 1979. At the 60-m station, in addition to the current meters, a bottom tripod system was deployed. At the 234-m station, an instrument package with 35-mm camera, strobe, transmissometer, and compass was deployed. Data from current

meters were low-pass filtered with a digital filter and collected on magnetic tape. Hydrographic data were collected using expendable bathythermographs and salinity/temperature/depth meters. Suspended particulate matter samples were collected in 10- or 30-l Niskin bottles mounted on a rosette sampler. Three samples (1 m below surface, mid-depth, and 1 to 2 m above bottom) were taken at each of three stations. These samples were subsampled then filtered (Millipore 0.45 μm); filters were split, dried, weighed, and one split was ashed at 500°C while the other was examined with petrographic and scanning electron microscopes for elemental analyses. Nutrients (ammonia, nitrate, nitrite, phosphate, and silicate) were determined using standard colorimetric techniques. Sediment traps deployed near the bottom and at 40 m were used to estimate the flux of sediments between the seabed and the water column. Sediment samples were collected during 1979 and 1980 using piston cores, hydraulically damped gravity cores, and Smith-McIntyre grabs. Thirteen piston cores up to 10 m deep were sectioned and tested for shear strength, index properties, and interstitial gases.

During 1975 and 1977, along the southern margin of the Hudson Shelf Valley, shallow subsurface and surface features were surveyed using subbottom profilers (Uniboom, and minisparker) and side-scan sonar, respectively. Instrumentation for deep seismic profiles included air gun (40 in³), sparker unit (800 joule), and echosounder (3.5 kHz). Direct observations were made during 15 submersible dives from 30 July to 3 August 1978. Grab samples, 35-mm photographs, and remote videotapes were taken during each dive.

SIGNIFICANT CONCLUSIONS: Tidal currents, mostly affected by Gulf Stream rings, were weaker in the Mid-Atlantic Bight than on Georges Bank. Only the finest sediments were transported by currents, and the highest concentration of suspended sediment occurred in the "Mud Patch" region south of Martha's Vineyard. This was considered an area of active deposition and a potential pollutant sink. A sediment slump was located on the shelf between Lindenkohl and South Tom's Canyon off New Jersey. Canyon thalwegs should be viewed with caution as potential structure sites due to high erosion potential. A previously unknown buried valley extending across the shelf under the Hudson Divide, southwest of the present-day Hudson Channel, was detected.

STUDY RESULTS: Tidal currents in the Mid-Atlantic Bight followed an elliptical path during each tidal cycle, with the major axis of these ellipses oriented perpendicular to local isobaths. Tidal height at the edge of the Mid-Atlantic OCS was uniform with an amplitude of about 40 cm. Onshore currents reached a maximum about 3 h before high tide. Tidal current speeds, measured 1 m above the bottom, were 7 cm s⁻¹. At the shelf break near Wilmington Canyon, bottom currents were affected by Gulf Stream rings; clockwise circulation caused net flow to the northeast of the outer shelf for 15 to 20 days. Gulf Stream rings did not affect alongshelf flow at 60 m depth. Maximum surface currents associated with these rings reached 30 cm s⁻¹. Near-surface currents were driven by prevailing winds; net long-term surface flows had off-shelf components of 1 to 2 cm s⁻¹. At the 234-m station, very fine sediment (<62.5 μm in diameter) were occasionally transported by near-bottom currents, and sediments greater than 125 μm in diameter were seldom transported. A net down slope movement of fine suspended matter was observed, but near-bottom currents often prevented deposition of this material. Highest concentrations of suspended matter occurred over the "Mud Patch" region south of Martha's Vineyard, where a pronounced nepheloid layer was observed. Residence time of suspended matter in the nepheloid layer was approximately 5 h on Georges Bank, 1.3 days on the "Mud Patch," and 2 days on the Mid-Atlantic shelf. Deposited sediments may undergo rapid mixing (to 28 cm) in surficial sediment layers, indicating a similar fate for contaminants. Tests for geotechnical properties showed the sediments on the continental slope

near Baltimore Canyon to be complex. Sediment composition was sands, silts, and clays which ranged from low to high plasticity. Surficial sediments were considered stable, though excess pore pressures may exist in some areas. Gas-charged sediments ranged from less than 10 ppm to greater than 10,000 ppm, with concentrations of methane found in slope sediments near South Tom's Canyon. Most interstitial gas was methane and higher homologues, possibly originating from preexisting natural methane hydrates. Cyclic loading resulting in bubble coalescence and increased pore pressures at greater burial depths could present stability problems.

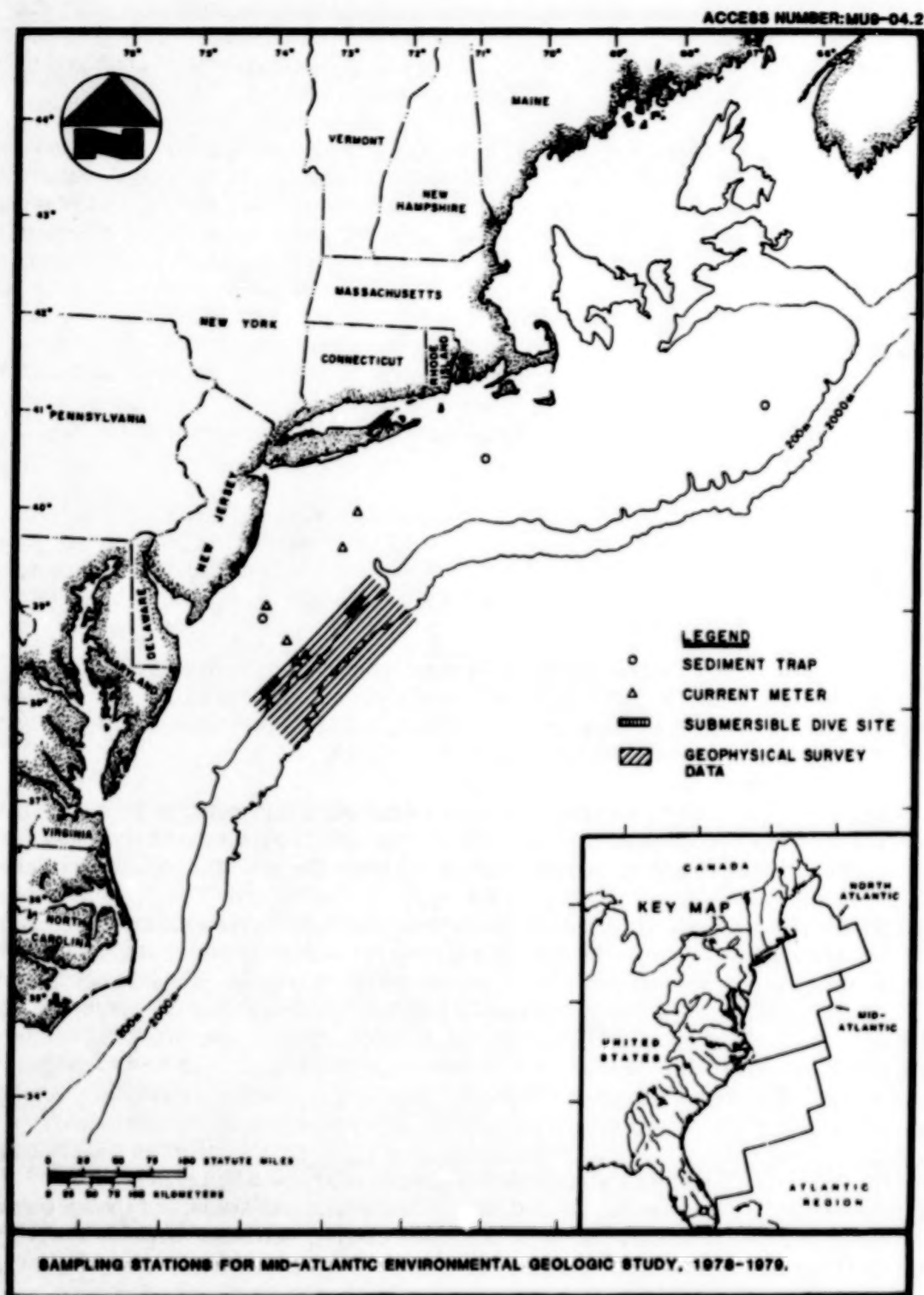
Subbottom stratigraphic investigations revealed a previously undetected buried valley extending across the shelf under the Hudson Divide. This valley was capped by 10 to 30 m of sediment which was overlain by interbedded layers of marine sand and mud. No shallow faulting was observed. On the continental slope off New Jersey, Pleistocene sediment was about 450 m thick between Lindenkhof and South Tom's Canyon, and thinned to nearly zero or absent on the mid- and lower slope. Five slump or slide features were identified in Pleistocene slope sediments. Submersible observations indicated bioturbation to be prevalent in or near canyon heads as opposed to intercanyon slope areas. Faunal density and diversity were greater near canyon heads and near-bottom currents were weaker. Iron stained sands were observed on the shelf, and shelf break sediments were dominated by sandy silts. In Carteret Canyon and South Tom's Canyon, silty sediments covered greenish clay outcrops. Conspicuously hazardous slump features were not observed during submersible dives.

STUDY PRODUCT(S): Robb, J. M. (ed). 1982. Environmental Geologic Studies in the Mid-Atlantic Outer Continental Shelf Area. Results of the 1978-1979 Field Seasons. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB83-147934. Contract No. AA551-MU8-21 and AA551-MU9-04. 296 pp. + plates.

Robb, J. M. 1982. Summary of Environmental Geologic Studies in the Mid-Atlantic Outer Continental Shelf Area. Results of the 1978-1979 Field Seasons. A report by the U.S. Geological Survey for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Contract No. AA551-MU8-21 and AA551-MU9-04. 38 pp.

Under MU8-21, other publications include a series of journal articles (Knebel, 1979, 1980; Knebel and Carson, 1979; 2 articles by Knebel et al., 1979), conference proceedings or abstracts (Knebel and Carson, 1977; Knebel and Wood, 1978; Robb et al., 1979; Twichell et al., 1979), and notes (Slater et al., 1979), as well as U.S. Geological Survey Open File Reports 79-1351 (Schlee et al., 1979) and 80-935 (Robb, 1980). Under MU9-04, other publications include U.S. Geological Survey Open File Reports 79-580 (Twichell, 1979), 80-934 (Robb, 1980), 81-239 (Booth, 1981), 81-366 (Olsen et al., 1981), 81-733 (Booth et al., 1981), 83-353 (Robb, 1983), 81-968 (Slater et al., 1981), and 85-351 (Booth, 1985). Additionally, conference proceedings (Butman, 1980; Robb and Kirby, 1980; Hampson et al., 1982), abstracts (Hampson et al., 1980; Hathaway et al., 1980; Robb et al., 1981; Robb et al., 1982; Harris and Robb, 1982), and a miscellaneous USGS field investigation map (Robb and Kirby, 1980) were produced.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Geological Studies of the U.S. Atlantic Outer Continental Shelf.

REPORT TITLE: Environmental Geologic Studies on the United States Mid and North Atlantic Outer Continental Shelf Area, 1980-1982. Vol. I, Executive Summary; Vol. II, Mid-Atlantic Region; Vol. III, North Atlantic Region.

CONTRACT NUMBER(S): BLM: IA2-26; MMS: 14-12-0001-29196.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982.

COMPLETION DATE OF REPORT: 1983.

COST(S): FY 1982: \$1,155,279; Cumulative Project Cost: \$1,155,279.

PROJECT MANAGER(S): H. Knebel, B. McGregor.

AFFILIATION: U.S. Department of the Interior, U.S. Geological Survey.

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PRINCIPAL INVESTIGATOR(S)*: J. Booth, M. Bothner, G. Brooks, B. Butman, R. Circe, S. Conley, A. Dahl, L. Doyle, F. Foley, Jr., E. Forde, P. Gibson, J. Hampson, Jr., V. Henry, J. Kellman, J. Kirby, D. Lambert, C. McClennen, B. McGregor, J. Moody, M. Noble, P. Pinet, P. Popenoe, W. Ryan, W. Stubblefield, D. Twichell.

KEY WORDS: North Atlantic; Mid-Atlantic; New Jersey; Georges Bank; geology; physical oceanography; transport; slope; rise; canyon; sediment; geophysical; submersible; Wilmington Canyon; South Wilmington Canyon; Berkeley Canyon; Lydonia Canyon; Oceanographer Canyon.

BACKGROUND: The prospect of oil and gas exploration and potential production on the continental slope off the eastern United States has created the need for surficial geologic studies of the slope. The present study was conducted by the U.S. Department of the Interior, U.S. Geological Survey to provide information needed to properly manage oil and gas activities in the deepwater slope environment.

OBJECTIVES: (1) To describe the mechanisms, processes, and sediment properties that influence sediment and pollutant transport into and through submarine canyons on the slope and rise; (2) To identify and map areas of mass sediment movement and to identify mechanisms contributing to sediment instability; (3) To assess the geotechnical properties of the sediments in areas encompassed within Lease Sales 49, 52, and 59; (4) To estimate the extent and rate of bottom sediment movement and to identify the major processes causing sediment movement with respect to seasonal variability and dynamics of currents; (5) To determine the magnitude and potential

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geological hazards in Lease Sale 59 areas through historical data review and field surveys; and (6) To define the shallow subbottom stratigraphy and to identify potential geological hazards for the nearshore environment in the Mid-Atlantic.

DESCRIPTION: Twenty-six cruises were conducted over the three-year period from 1980 to 1982 covering the slope and rise of the Mid-Atlantic and North Atlantic. Mid-Atlantic cruises were concentrated off New Jersey. North Atlantic cruises were mostly along Georges Bank. The cruises involved geophysical mapping, core samples for geotechnical and sediment movement analyses, deployment and recovery of instrument tripod arrays, and submersible dives. Geophysical mapping was accomplished using seismic-reflection airgun (40-in.³), 3.5 kHz echo sounder, minisparker (800 joule), Uniboom, and midrange side-scan sonar. Sediments were collected with piston corer, gravity corer, grab sampler, bag sampler, and sediment traps. Near-bottom currents and sediment movement were recorded from tripod systems equipped to measure temperature, salinity, transmissivity, current velocity, and current direction. Time-lapse photographs of the sea floor were used in conjunction with current meter and transmissivity data. Three dives in the DSRV ALVIN on the continental rise in Wilmington and South Wilmington Canyons in water depths of 2,300 to 2,400 m allowed examination and sampling of features located in the side-scan sonar data. Geotechnical characterization and mass movement potential were examined from 8-m and 10-m piston cores. Shear strength was tested using 12.7 mm laboratory vane at 0.50 mm intervals. Index properties (water content, plastic limits, and grain-specific gravity) were determined. Triaxial and consolidation tests were also conducted.

SIGNIFICANT CONCLUSIONS: The patterns and morphologies of submarine canyons and gullies of the slope support the concept that canyons are important transport pathways on the continental margin. Seafloor processes vary among canyons, despite their proximity. Geophysical findings documented the occurrence of erosion on the continental slope and rise. In general, surficial sediments were found to be stable, however, local conditions may vary and affect this stability. Ocean currents were responsible for transporting sediment into and through submarine canyons.

STUDY RESULTS: Side-scan sonar demonstrated that submarine canyons were morphologically similar to subaerial fluvial systems. These similarities included dendritic patterns, meander patterns, and implied relationships of maturity and gradient to channel morphology. Submersible dives confirmed these interpretations. At the mouth of Berkeley Canyon, submersible observations revealed a set of features cut into chalky sedimentary rocks of Eocene age. The furrows were 10 to 50 m apart, 4 to 13 m deep, and 3 to 5 m wide with flat floors of fine-grained, flocky, unconsolidated sediment. The North Atlantic Lydonia and Oceanographer Canyons exhibited different characteristics despite their proximity. In contrast to the fine-grained deposits in Lydonia Canyon, the floor of Oceanographer Canyon was covered by sand waves. This indicated active reworking of the bottom by strong currents. Lydonia Canyon appears to be an erosionally young feature, or erosion and deposition occur periodically within the canyon.

Sediments of the Mid-Atlantic and North Atlantic continental slope displayed considerable geotechnical variability. Undrained shear strength ranged over two orders of magnitude, plasticity ranged from high to low, sensitivity ranged from insensitive to slightly quick, and sediments may be normally consolidated to heavily overconsolidated. Despite this range of conditions, surficial sediments fall into the Unified Soil Classification System "CH" category (inorganic clays of high plasticity). With the exception of canyons and canyon systems, stability analyses showed that the slope is generally stable for drained and undrained conditions. Some areas would be vulnerable if

subjected to relatively minor earthquake-induced ground accelerations, excess pore pressures from gas or other sources, or slight increases in gradient from undercutting or oversteepening.

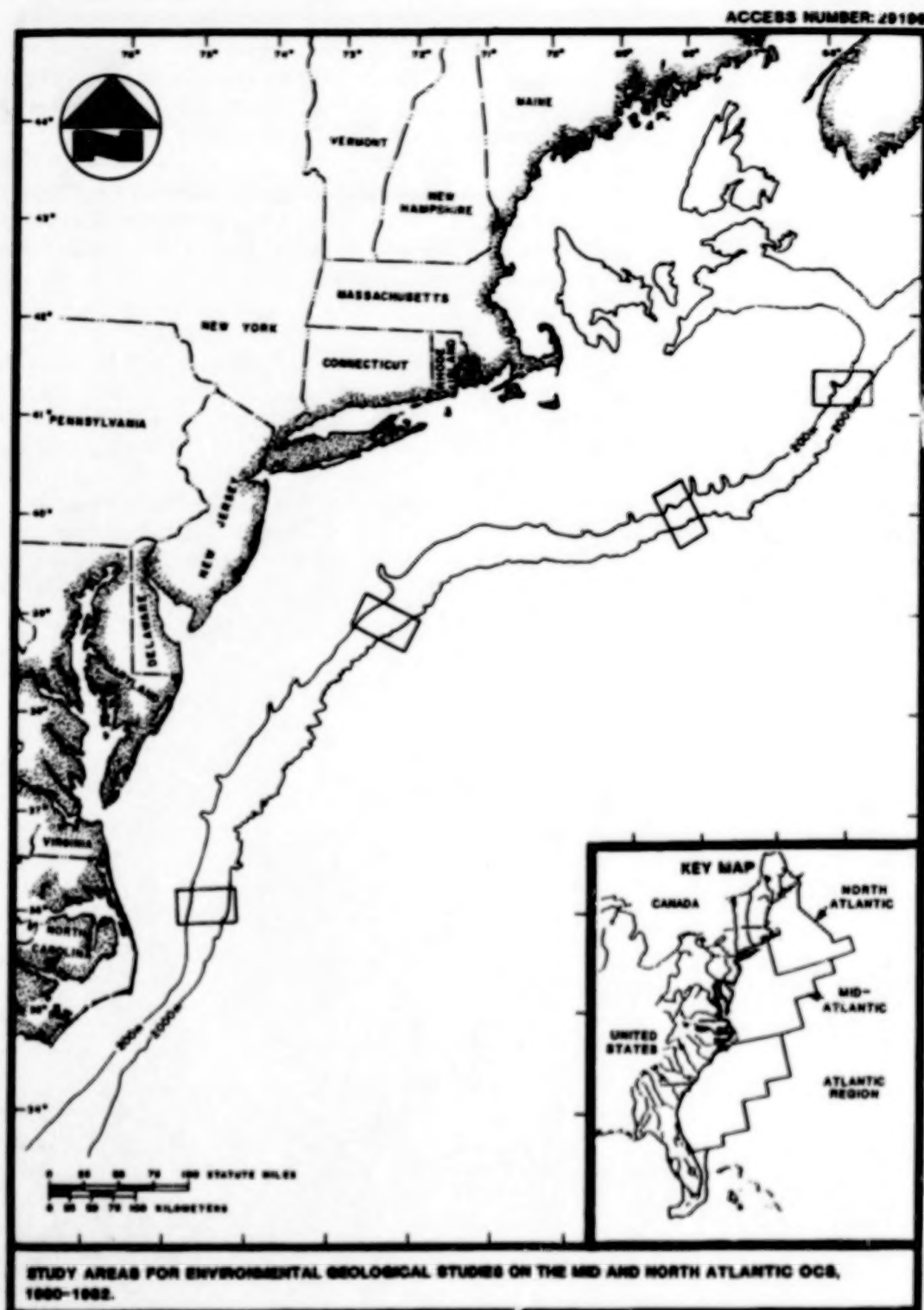
Near-bottom observations showed that sediment resuspension is primarily by surface waves associated with storms on Georges Bank and in the Middle Atlantic Bight. Bottom sediments were constantly reworked and scoured by semidiurnal tidal currents in some areas. Fine material was transported to the west and southwest along isobaths during major storms.

STUDY PRODUCT(S): McGregor, B. 1983. Environmental Geologic Studies on the United States Mid and North Atlantic Outer Continental Shelf Area, 1980-1982. Vol. I, Executive Summary. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84187939. Contract No. 14-12-0001-29196. 51 pp.

McGregor, B. (ed.). 1983. Environmental Geologic Studies on the United States Mid and North Atlantic Outer Continental Shelf Area, 1980-1982. Vol. II, Mid-Atlantic Region. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84187947. Contract No. 14-12-0001-29196. 345 pp.

McGregor, B. (ed.). 1983. Environmental Geologic Studies on the United States Mid and North Atlantic Outer Continental Shelf Area, 1980-1982. Vol. III, North Atlantic Region. A final report by the U.S. Geological Survey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84187954. Contract No. 14-12-0001-29196. 333 pp.

**P.I.s affiliation may be different than that listed for Project Manager(s).*



VI

OTHER

These are projects that include special studies and analyses designed to provide complete coverage of issues related to the Outer Continental Shelf leasing program and that do not appropriately fall into any of the other topic categories.

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STUDY TITLE: Canyon and Slope Processes Study.

REPORT TITLE: Canyon and Slope Processes Study.

CONTRACT NUMBER(S): BLM: CT0-59; MMS: 14-12-0001-29178.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1980.

COMPLETION DATE OF REPORT: August 1983.

COST(S): FY 1980: \$4,651,777; Cumulative Project Cost: \$4,651,777.

PROJECT MANAGER(S): M. Rawson.

AFFILIATION: Columbia University.

ADDRESS: Lamont-Doherty Geological Observatory, Palisades, New York 10964.

PRINCIPAL INVESTIGATOR(S)*: F. Gandarillas, W. Gardner, P. Gibson, B. Hecker, K. Hunkins, D. Logan, J. Stepien.

KEY WORDS: North Atlantic; Mid-Atlantic; Baltimore Canyon; Lydonia Canyon; physical oceanography; slope; commercial fishing; currents; hydrography; sediment; nutrients; abundance; distribution; infauna; benthos; mitigation; transport; suspended matter; feeding; zooplankton; benthic photographs.

BACKGROUND: The seafloor off the east coast of the United States is incised by large valleys which head on the Atlantic Outer Continental Shelf (OCS) and cut downward across the slope and rise. There are 26 major submarine canyons between Nova Scotia, Canada and Cape Hatteras, North Carolina. These canyons appear to be sites of enhanced biological productivity, with extensive commercial fishing for squid, lobster, and finfishes. Submarine canyons are anticipated sites for exploratory drilling and potential petroleum production wells. Foreseeing a potential conflict between the commercial fishing and petroleum exploration interests, the Bureau of Land Management contracted this study to provide a factual basis for future discussions and regulatory decisions concerning the physical and biological processes operating in submarine canyons and on the slope, and the processes that might transmit the effects of OCS activities to benthic communities.

OBJECTIVES: (1) To characterize the currents and hydrography within submarine canyons and on the slope; (2) To document the along-slope structure of currents and the influence of canyons on slope currents; (3) To characterize the suspended sediment and nutrient exchange between canyons and the adjacent shelf and slope; (4) To determine the abundance and distribution of epifaunal

communities in selected canyon and slope areas; (5) To determine the abiotic and biotic processes affecting the distribution and abundance of epifaunal communities; (6) To identify the communities which may be affected by oil and gas operations; and (7) To identify measures for alleviating or eliminating the effects of oil and gas operations on the epifaunal communities.

DESCRIPTION: Five areas were examined during this three-year study. These included Baltimore Canyon in the Mid-Atlantic, Lydonia Canyon in the North Atlantic, and three slope areas of high oil and gas industry interest. The slope areas included an area between Linderkohl and Carteret Canyons, an area between Toms and Meys Canyons (both in the Mid-Atlantic), and an area between Veatch and Hydrographer Canyons in the North Atlantic. Study depths ranged from 100 to 2,000 m. Baltimore Canyon and the two adjacent Mid-Atlantic slope sites were the scenes of physical oceanographic, sediment transport, nutrient, and zooplankton studies. Megafaunal assemblages were assessed in Lydonia and Baltimore Canyons, and all three slope sites.

SIGNIFICANT CONCLUSIONS: Results of this study showed that megafaunal assemblages in canyons may be substantially different from the surrounding slope area. Submarine canyons provide habitat for a variety of unique taxa and act as refuges for large refuge populations of sessile filter-feeding anemones, corals, and sponges. Growth rates in deepsea organisms are generally slow, and recovery of a submarine canyon megafaunal community from any major environmental impact would be slow. Canyon epifaunal assemblages should be regarded as fragile, compared to those of the shelf and slope. Taxonomic richness was highest in areas of hard substrate whether in canyons, on the shelf, or on the slope.

STUDY RESULTS: Peak bottom current speeds of 106 cm s^{-1} were observed in the axis near the head of the Baltimore Canyon at depths of 275 m. At 594 m, a current of 95 cm s^{-1} was also reported from the axis station. Currents of this magnitude were not anticipated and were greater than any observed on the adjacent shelf-slope area. The highest current speed observed on the shelf itself was 81 cm s^{-1} in 100 m of water just above the canyon heads. Spectral analysis showed the energy of the fluctuating currents to be concentrated in two frequency bands, suggesting a nearly semi-diurnal tidal frequency and the other indicating the existence of an internal or baroclinic tide. The mean current flow near the surface over the slope area and Baltimore Canyon is southwestward paralleling the shoreline at speeds of 10 to 15 cm s^{-1} . Only at depths below 100 m does canyon topography influence shelf current direction. Mean currents along the canyon axis are down canyon from the head to a depth of 400 m and up canyon in the 600- to 1,000-m depth range, forming a zone of convergence between 400 and 500 m. Here water must be carried upward and dispersed along the thermocline, although this is not conclusively demonstrated in the present study. Bottom currents were negligible below 1,000 m.

Resuspension of particulate matter within the canyon occurred predominantly along the canyon axis and at tidal frequencies. Sediment transport generally followed the net transport of the water: on the shelf it was parallel to the coast, southwest along the isobaths; in the canyon it was down canyon from the head to 400 m then strongly up canyon at 600 m; and virtually nonexistent in the 1,000 m range. Seaward transport of particulate matter occurred in the form of turbidity layers which detached and moved outward along density gradients. Transport along the canyon walls and adjacent slope areas was very small compared to the canyon axis.

Surface and near-bottom nutrient concentrations in the Baltimore Canyon area suggest their distribution is influenced primarily by the mean circulation patterns. Surface concentrations of

phosphate, silicate, and nitrate varied seasonally as a result of biological activity in the upper water column. Concentrations increased with depth, reaching a maximum from 300 to 600 m at all stations.

Total megafaunal abundance was high along the shelf and upper slope (100 to 600 m), low at mid-slope depths (below 1,400 m), then high again at lower slope depths (below 1,400 m). Five major depth zones with characteristic common taxa were found between 100 and 2,000 m. Depths of transition between these zones varied slightly from area to area. Substantial overlap in taxa between adjacent zones indicated a pattern of gradual species replacement along a depth gradient. In the North Atlantic, faunal densities in Lydonia Canyon were considerably higher than at comparable depths on the shelf and slope. In the Mid-Atlantic, no consistent differences in megafaunal densities between the Baltimore Canyon and adjacent slope areas were detected.

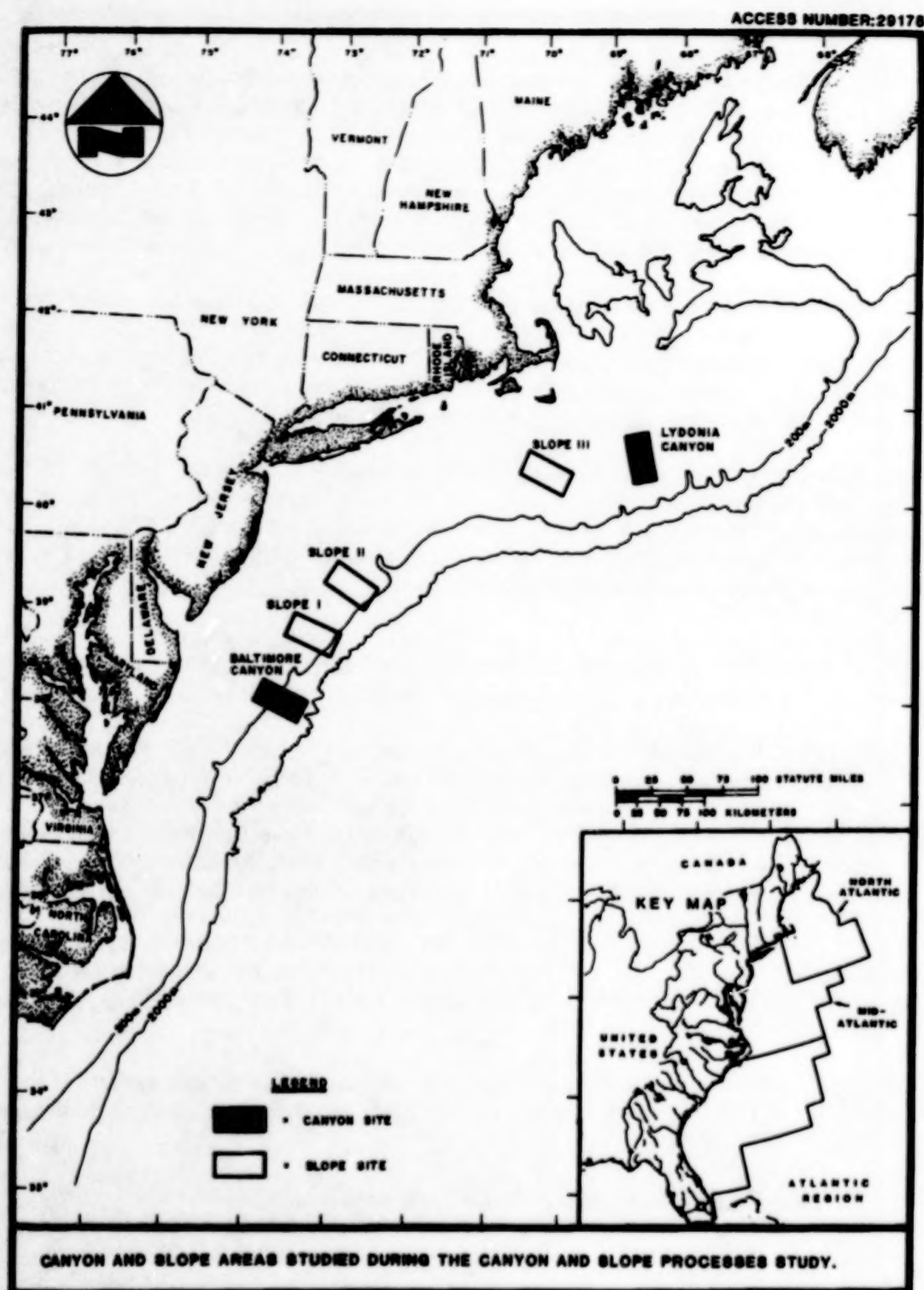
In the Mid-Atlantic, canyon and slope trophic patterns were similar: the shelf and upper slope showed dense populations of filter feeders and/or carnivore/ scavengers; the mid-slope sparse densities of carnivore/scavengers; and the lower slope fairly dense groups of deposit feeders and filter feeders. Lydonia Canyon showed dense populations of sessile filter feeders at the mid-slope depths because of increased hard substrate in those depth ranges.

Zooplankton biomass was highest at the surface over the shelf and decreased further offshore. Near bottom biomass was also highest at shelf stations. An increased species abundance and biomass was observed in the upper canyon relative to the rest of the canyon. This increase is consistent with observations of increased particle concentrations, nutrient concentrations, epifaunal distribution, and resuspension phenomena from this study.

STUDY PRODUCT(S): Lamont-Doherty Geological Observatory of Columbia University. 1983. Canyon and Slope Processes Study. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. Contract No. 14-12-0001-29178. 541 pp.

Samples collected during this study are archived at the following locations: zooplankton specimens, suspended sediment samples, and photographs are archived at Lamont-Doherty Geological Observatory; geology samples from submersible dives are archived at the U.S. Geological Survey (Woods Hole, Massachusetts) and National Oceanic and Atmospheric Administration (Rockville, Maryland); and voucher specimen collections of anemones are at the Museum of Comparative Zoology (Harvard) and all other epifaunal groups are at the Smithsonian Institution (Washington, D.C.).

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Study of Environmental Impacts of Utilizing Pipeline Corridors in the Mid-Atlantic OCS.

REPORT TITLE: Identification and Assessment of Impacts Associated with the Construction and Operation of Submarine Pipelines on the Mid-Atlantic Outer Continental Shelf. Final Report.

CONTRACT NUMBER(S): BLM: CT2-25; MMS: 14-12-0001-29195.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): Mid-Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982.

COMPLETION DATE OF REPORT: September 1983.

COST(S): FY 1982: \$150,000; Cumulative Project Cost: \$150,000.

PROJECT MANAGER(S): J. Brosius.

AFFILIATION: Rutgers, The State University of New Jersey, Center for Coastal and Environmental Studies.

ADDRESS: Rutgers University, Busch Campus, New Brunswick, New Jersey 08903.

PRINCIPAL INVESTIGATOR(S)*: J. Brosius, N. Psuty, C. Talbot.

KEY WORDS: Mid-Atlantic; New York; North Carolina; Chesapeake Bay; Delaware Bay; New York Bay; commercial fishing; pipeline; impacts; shellfish; canyon; endangered species; geophysical.

BACKGROUND: Oil and gas activity has been taking place along the Mid-Atlantic Outer Continental Shelf (OCS) since 1976. Although results of oil and gas exploration are inconclusive to date, a real potential exists for oil and gas production from the Mid-Atlantic OCS. Pipelines are considered one of the most likely transportation modes for the movement of petroleum resources from offshore to landbase facilities. Submarine pipeline development has the potential for affecting resources and uses of the Mid-Atlantic OCS. To ensure proper pipeline development and environmental safety, the Minerals Management Service (MMS) initiated environmental and impact assessments related to pipeline construction in the Mid-Atlantic OCS.

OBJECTIVES: (1) To characterize the physical, biological, and cultural/economic systems in the Mid-Atlantic OCS; (2) To review pipeline operation and impacts in other areas; and (3) To evaluate potential impacts and mitigation.

DESCRIPTION: This study is a compilation and synthesis of existing information. The study area is comprised of the Hatteras-Cape Cod Shelf and a small area of the Florida-Hatteras Shelf. Information concerning the geology, socioeconomics, and biology of the Mid-Atlantic OCS extending from Long Island, New York to just south of Cape Hatteras, North

Carolina is considered as they relate to pipeline construction and potential impacts. Pipeline operation and impact information is gathered from areas other than the Mid-Atlantic OCS. This environmental assessment should serve as a source document for preparation of submarine pipeline development in the Mid-Atlantic OCS. A comprehensive list of references is presented to assist in similar investigations.

SIGNIFICANT CONCLUSIONS: Relatively few exclusionary or high impact areas exist in the study area, although mitigation measures and processes to minimize impacts are necessary to prevent detrimental effects to adjacent areas. Certain dumpsites, a marine sanctuary, areas of surf clam harvesting, and canyons and canyon heads should be avoided when considering pipeline development and operation. Safe development and operation is dependent on route selection that can physically support the structure and minimize biological as well as cultural/economic impacts. The Mid-Atlantic OCS appears suitable for pipeline development when considering the geophysical characteristics of the area. Biological impacts may result from pipeline development and operation, however, impact severity can not be determined because of the numerous variables involved.

STUDY RESULTS: The Mid-Atlantic OCS is flat with a seaward dip of about 1 to 2 degrees. Deposition and degradation processes have left a surficial sand sheet (average thickness 5 to 7 m) over a layer of clay. Numerous submarine canyons occur in the study area. Canyon walls may be nearly vertical, however, slopes of about 30° are more common. These canyons are also areas of sediment slumping and sliding. Shallow faults are relatively uncommon but deep faults are common in the study area. Sand ridges are common shelf features, being most prominent off New Jersey and Long Island, New York. Incised river channels dominate the shelf, with many smaller channels distributed throughout the study area.

Man-made features are present throughout the Mid-Atlantic OCS. Traffic Separation Schemes and Precautionary Areas are located at Chesapeake Bay, Delaware Bay, and New York Bay. Active dumpsites are also present. Four Trans-Atlantic submarine cables are located in the study area. Nearly a thousand shipwrecks are mapped within the study area.

The Mid-Atlantic OCS supports numerous commercial fish and shellfish fisheries. Fisheries can account for \$30,000,000 annually. Surf clam, ocean quahog, sea scallop, lobster, and deep-sea red crab comprise almost the entire shellfish catch. Nineteen species of fish comprise the majority of the commercial catch. Recreational fishing occurs year round in the study area. Most commercial and recreational fishing occurs inshore, however, offshore areas (e.g., canyons and shipwrecks) are utilized.

The Mid-Atlantic OCS fish fauna is highly variable as many species are transient to the area. Fish movements and distributions vary with life cycle stages. The study area, particularly the inner shelf, is important for spawning and as nurseries for many commercial and recreational species.

The Mid-Atlantic OCS has perhaps the largest commercial shellfish beds in the United States. Surf clams inhabit the surf zone to a water depth of about 46 m. The surf clam is sedentary and subject to over exploitation; the annual surf clam yield is about 40 million pounds per year. Ocean quahogs are distributed throughout the study area, however commercial quantities are located at depths of 25 to 60 m. The sea scallop is found primarily on the outer shelf at depths of 40 to 100 m.

A variety of corals occur on the shelf edge and in submarine canyons. Both scleractinians (hard corals) and alcyonarians (soft corals) are present in the study area. Many hard-substrate restricted coral species of the Mid-Atlantic OCS may be present only in canyons.

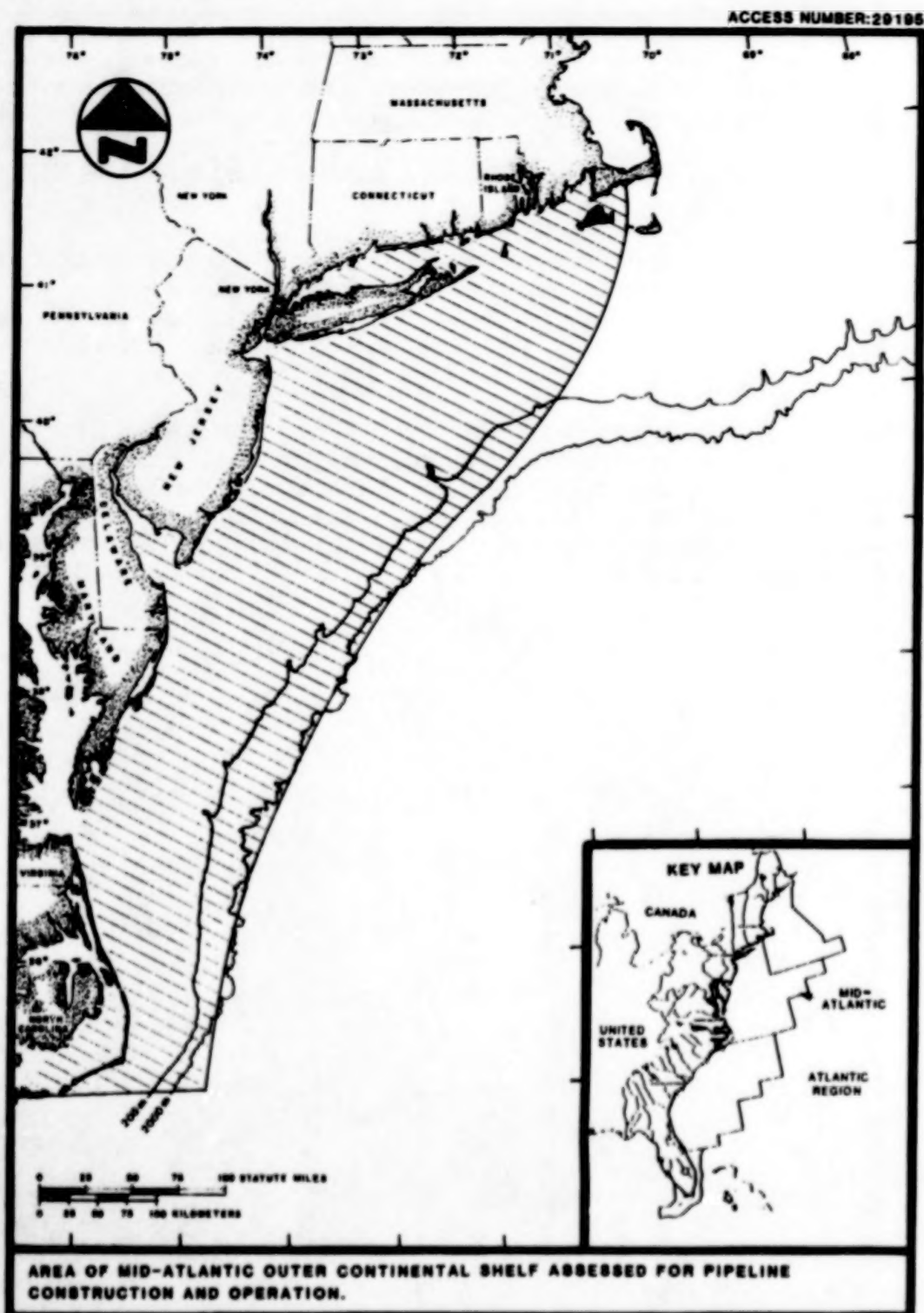
Submarine canyons are ecologically unique and biologically important. Canyons are areas of faunal aggregation that support a unique assemblage of benthic fauna. Circulation patterns associated with submarine canyons account for a large nutrient input which supports a variety of trophic levels.

Nine endangered or threatened species (five cetaceans and four turtles) occur in the Mid-Atlantic OCS area.

Geophysical features that could represent impediments to pipeline development consist of sediment movement, seismic activity and faulting, and irregular seafloor topography. Potential cultural/economic impacts may be related to anchor damage, fishing activities, submarine cables, military use, and shipwrecks. Biological disturbances are expected to occur during both development and operation of the pipeline.

STUDY PRODUCT(S): Brosius, J. E., C. W. Talbot, and N. P. Psuty. 1983. Identification and Assessment of Impacts Associated with the Construction and Operation of Submarine Pipelines on the Mid-Atlantic Outer Continental Shelf. Final Report. A final report by the Center for Coastal and Environmental Studies, Rutgers, The State University of New Jersey for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84187863. Contract No. 14-12-0001-29195. 159 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: An Environmental Summary of the U.S. Atlantic Continental Rise.

REPORT TITLE: Environmental Summary of the U.S. Atlantic Continental Slope and Rise, 28-42°N.
Vols. I and II.

CONTRACT NUMBER(S): BLM: CT2-47; MMS: 14-12-0001-29200.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic; Mid-Atlantic; South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982.

COMPLETION DATE OF REPORT: 1984.

COST(S): FY 1982: \$209,923; Cumulative Project Cost: \$209,923.

PROJECT MANAGER(S): J. Milleman.

AFFILIATION: Marine Geoscience Applications, Inc.

ADDRESS: 479 West Falmouth Highway, West Falmouth, Massachusetts 02543.

PRINCIPAL INVESTIGATOR(S)*: R. Gagosian, A. Gaines, T. Joyce, W. Schmitz, B. Tucholke, P. Wiebe.

KEY WORDS: North Atlantic; Mid-Atlantic; South Atlantic; Georges Bank; Cape Hatteras; Blake Plateau; biology; slope; rise; synthesis; sediment; literature review; historical review; meteorology; physical oceanography; geology; transport; Gulf Stream; Western Boundary Undercurrent; nutrients; hydrocarbons; trace metals; plankton; infauna; faunal zones; commercial fishing; minerals.

BACKGROUND: The report is a synthesis and evaluation of environmental information concerning the continental slope and rise off the eastern United States, Atlantic Continental Slope and Rise (ACSAR). This information is needed by the Minerals Management Service to make management decisions regarding effects of oil and gas development in and surrounding this region.

OBJECTIVES: (1) To identify, analyze, and summarize existing biological, chemical, geological, meteorological, and oceanographic information related to the ACSAR region.

DESCRIPTION: The ACSAR region of the eastern United States is defined as the area between latitudes of 28 and 42°N and between water depths of 200 and 4,000 m. Environmental data and information were collected from published papers and reports, unpublished reports, reported but unpublished data, and personal communication from scientific colleagues. The topics covered in the document include meteorology and air-sea interactions, physical oceanography, geology, chemistry, biology, human activities and impacts, and future study needs.

SIGNIFICANT CONCLUSIONS: Oceanographic phenomena and processes of the ACSAR area have been defined in existing literature. Three areas need to be addressed: (1) examination of regional mesoscale and microscale processes and events using current technology; (2) a better understanding of fluxes (rates of transport/transfer/reproduction of water, particles, chemical species or organisms in the study area); and (3) more complete utilization and interpretation of existing data sets.

STUDY RESULTS: Storms are of central importance when considering atmospheric circulation in the ACSAR region. The general circulation pattern is dominated by the "Bermuda High" throughout most of the year, producing southwesterly winds. In winter, this is displaced by a low pressure system off Greenland, producing westerly to northwesterly winds. Two major categories of storms are superimposed on this mean pattern: (1) tropical cyclones; and (2) seven categories of extra-tropical storms.

Water characteristics of the ACSAR region change dramatically at Cape Hatteras, where the Gulf Stream diverges from the coast. Southwest of Hatteras, the Stream impinges directly upon the slope, while the Sargasso Sea overlies the Blake-Bahama Outer Ridge and associated mid-depth features. Northeast of Hatteras, the Stream meanders offshore; the space between the Stream and the shelf is occupied by slope water. Continuity exists between the region below about 2,000 m, where the Western Boundary Undercurrent (WBUC) flows to the southwest along the continental rise. ACSAR region water masses can be subdivided vertically by temperature into three main classes: (1) deep water, colder than 4°C, about two-thirds of all water; (2) the thermocline, 4 to 17°C, about 25% of the total; and (3) warm water, warmer than +17°C, about 8% of the total. Seasonal variability penetrates only to water depths of about 200 m. A unique ACSAR region feature is that it contains the strongest low frequency currents in the world ocean—the Gulf Stream and the WBUC.

The continental shelf slope extends from the shelf-slope break (60 to 200 m) to 2,000 m; width varies from 10 to 50 km. Between Georges Bank and Cape Hatteras, the slope is cut by at least 70 large canyons; in contrast, few canyons exist on the Florida-Hatteras Slope, probably because of the effect of the Gulf Stream. The continental rise is divided into the upper rise (2,000-3,000 m), central rise (3,000-4,000 m), and lower rise (greater than 4,000 m). The Blake Plateau lies between 400 to 1,200 m in water depth. Two groups of seamounts exist off the northeastern ACSAR.

The "mud line" occurs at 250-300 m, below which silt and clay-size sediments predominate. On the Blake Plateau, high carbonate, biogenic sands and gravels predominate. Detrital sediments dominate the upper slope. Because of variable texture, composition, and age, geotechnical properties of slope sediments have a predictably great variability; rise sediments, on the other hand, are more homogeneous. Accumulation rates on the slope vary (slightly lower off the rise) with some areas exhibiting negative accretion. The dominant sedimentary process in the ACSAR area is gravity controlled downslope movement (i.e., slumps, slides, debris flows, and turbidity currents).

The basement lies 8 to 10 km beneath sea level on the continental rise. The continental-ocean transition in crust occurs at the inferred "basement ridge" beneath the continental slope and is coincident with the East Coast Magnetic Anomaly; the ridge is overlain by reefal limestones. Crust age at the Jurassic Magnetic Quiet Zone is 141-161 million years ago (mya), but initial separation of North America from Europe/North Africa may have begun 175 mya. Seismicity in the ACSAR area is generally poorly known.

Water column chemical regime and bottom sediments in the ACSAR are only partly understood; some regional concentrations are documented for some parameters but fluxes and processes are not. Water column distribution of dissolved nutrients vary with water mass and depth. Data exist on trace metal concentrations, radionuclides, and hydrocarbons.

Distribution of plants and animals in the ACSAR region follows the general pattern outlined below. The Gulf Stream, which separates the Sargasso Sea and slope water, forms a sharp biogeographic

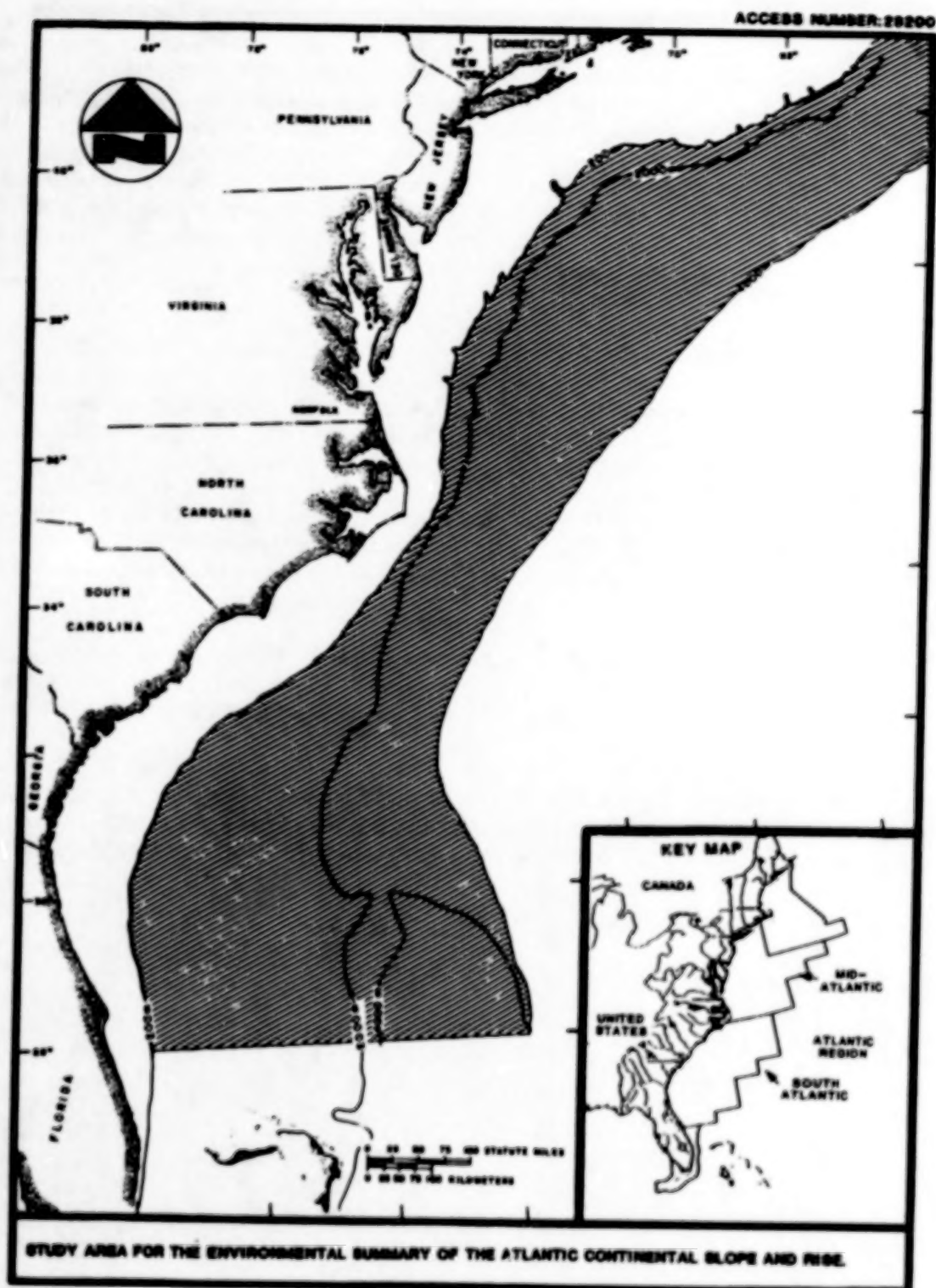
boundary between the North Atlantic temperate and North Atlantic subtropical regions. The north edge of the Gulf Stream is the southern limit for some cold water organisms and the northern limit for other warm water organisms. The current also serves to transport tropical Caribbean biota northward, sometimes well north of Cape Hatteras. Studies have been conducted on marine bacteria, protozoa, foraminifera, radiolaria, and ciliates in the water column in the ACSAR region. Generally, the patchy phytoplankton distributions in the ACSAR region are dictated by water mass properties and season. Phytoplankton species composition changes in an offshore direction with decreasing diatom importance coincident with increasing dominance of coccolithophorids. Zooplankton are well-studied in the ACSAR region; however, delineating distribution, abundance, and seasonal cycles of zooplankton is affected by problems such as patchiness, hydrographic variability, and net avoidance by large organisms. Neuston data in the ACSAR are scarce. Both abundance and size of bottom dwelling (benthic) organisms decrease with increasing water depth, but average weight of individual fish increases below 500 m.

Resources and environmental features of the ACSAR region provide both opportunities and constraints with regard to human activities. National and international laws govern human activity in the area. Active commercial fisheries exist for tilefish, billfish, sharks, lobster, and red crab for U.S. fishermen. Fisheries exist for cod, haddock, silver hake, red hake, scup, seabass, summer flounder and red fish although less than 0.1% of the total catch is by U.S. fishermen. Major mineral resources in the ACSAR area include sand and gravel, manganese nodules, and phosphorites. Oil and gas may be present. Deepwater Dumpsite 106 is located within the ACSAR region and has received industrial chemical wastes and explosives; an adjacent deepwater site is proposed for incineration of hazardous chemicals aboard special ships. Ten telecommunication cables cross the ACSAR.

STUDY PRODUCT(S): Marine Geoscience Applications, Inc. 1984. Environmental Summary of the U.S. Continental Slope and Rise, 28-42°N. Vol. I. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-29200. 442 pp.

Marine Geoscience Applications, Inc. 1984. Environmental Summary of the U.S. Continental Slope and Rise, 28-42°N. Vol. II. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-29200. 494 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



VII

PHYSICAL OCEANOGRAPHY

Physical oceanography projects consist of studies of the circulation patterns of the Outer Continental Shelf and the mechanisms creating these patterns. An understanding of the general dynamics allows for the support of diagnostic and predictive modeling efforts. The physical oceanography data collected by the Environmental Studies Program is used as an input to the Oil Spill Risk Analysis model.

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STUDY TITLE: Georges Bank Climatological and Oceanographic Analysis.

REPORT TITLE: A Climatologic and Oceanographic Analysis of the Georges Bank Region of the Outer Continental Shelf.

CONTRACT NUMBER(S): BLM: IA8-14.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978; 1979.

COMPLETION DATE OF REPORT: September 1980.

COST(S): FY 1978: \$209,847; FY 1979: \$185,000; Cumulative Project Cost: \$394,847.

PROJECT MANAGER(S): F. Godshall.

AFFILIATION: Marine Environmental Assessment Division, Center for Environmental Assessment Services.

ADDRESS: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Washington, D.C.

PRINCIPAL INVESTIGATOR(S)*: J. Bishop, F. Everdale, S. Fehler, R. Williams.

KEY WORDS: North Atlantic; Georges Bank; Gulf of Maine; physical oceanography; nutrients; hydrography; gyre; seasonality.

BACKGROUND: Georges Bank, located along the continental margin of the northeastern United States, is a designated oil and gas leasing area under control of the U.S. Department of the Interior (USDOI). The USDOI requires detailed characterizations of proposed exploration sites under its authority to ensure proper environmental protection. Ocean circulation patterns and their underlying causes are important to consider when assessing dispersal of pollutants or stability of engineered structures. Information contained in this report was the result of a project funded by the USDOI to provide a review of archived oceanographic data sources for the Georges Bank region and to suggest topics in need of further research.

OBJECTIVES: (1) To assess intraregional scale of circulation through the use of surface data, ship drift data summaries, modeling, and hydrographic data interpretation; (2) To provide information that can be used to guide future observation programs; (3) To produce regional scale distributions of variables; and (4) To locate deficiencies in archived data sources.

DESCRIPTION: Data sources were derived from files at the National Oceanographic Data Center (NODC) and the National Climatic Center (NCC). Information included meteorological data recorded from coastal observation stations in Brunswick, Maine; Portsmouth, New Hampshire; and Yarmouth, Nova Scotia; from offshore platforms at Georges Shoal; Nantucket Shoal; and Nantucket Light Station. Shipboard observations of wind, visibility, surface pressure, and temperature were also available. Most oceanographic data were recorded using mechanical and expendable bathythermographs and electronic salinity-temperature-depth (STD) meters calibrated with Nansen

reversing thermometers. Data from different instruments were treated separately to obviate individual biases. Surface wave height and wave period data were collected from surface (ship) observations.

Dissolved oxygen and nutrients (nitrate, nitrite, phosphate, and silicate) were also available in NODC files. Geographical distribution of water mass properties were objectively determined using a classification procedure (asymptotic singular decomposition). Winter and summer projections of surface drift trajectories were based on wind, residual current, and tide. Literature reviews supported any deductions derived from historical data.

SIGNIFICANT CONCLUSIONS: The prevailing surface wind pattern in the Georges Bank region varied from predominantly northwesterly in winter to southwesterly in summer. Seasonal circulation patterns were modeled, showing a cyclonic gyre in the Gulf of Maine and an anticyclonic gyre over Georges Bank. Wind driven circulation was approximately equal to tidal and regional circulation. Three fairly homogeneous water masses (shelf, midshelf, and slope) were identified that differed primarily in vertical mixing, as evidenced from salinity and temperature variations within each mass.

STUDY RESULTS: Surface wind was variable in all regions of the study area, but less so during summer months. From October through March, westerly and northwesterly winds prevailed. In summer, southwesterly winds were associated with subtropical anticyclones. Average wind speed in the southeastern region was greater than in other regions. Relative differences between inshore and offshore wind speed and direction were attributed to intraregional differences in air-sea temperatures. This information was incorporated into oil spill trajectory models along with intraregional tidal flow and residual current flow. Predictions from the model were of little value in real-time analysis problems. Advection fog was the most common preclusion to visibility. Visibility of less than 10 NM occurred over Georges Bank during spring.

Three quasi-homogeneous water masses were delimited using vertical distribution of salinity and temperature as variables in asymptotic singular decomposition analysis. Seasonal maps defined geographical location of these water masses. The three masses were: cool, low salinity shelf water; mixed midshelf (75 to 125 m) water; and slope water below 125 m. The water masses were indicative of source water and extent of vertical mixing. The lowest surface salinity (30.1 ppt) occurred off the Scotian Shelf; the highest (36.19 ppt) was recorded on the New England Slope during March. High salinity water emanated from the Northeast Channel to the Gulf of Maine, where mixing occurred. An intermediate layer existed in the Gulf of Maine and on the Scotian Shelf. Except for winter, the three water masses were stratified. Stratification should inhibit vertical transport of pollutants to subsurface layers. Waters shallower than 75 m were less stratified and subject to vertical mixing, explaining the cool summer and warm winter temperatures recorded in surface waters over Georges Bank. Hydrographic data summaries helped to identify predominant circulation patterns. General patterns included a cyclonic gyre over Georges Bank and an anticyclonic gyre in the Gulf of Maine. Georges Bank received flow from the Gulf of Maine during winter months. A cyclonic gyre was also associated with the Scotian Shelf and the adjacent Scotian Current, which carried low salinity waters that were riverine in nature into the Gulf of Maine. The circulation patterns described in this report agreed with traditional interpretations for the study area.

The local maximum of dissolved oxygen concentration (ca 7.0 mg l⁻¹) on Georges Bank in July was associated with cool water temperatures during that month. Generally, low dissolved oxygen concentrations were observed in waters offshore of the 200-m isobath. The Scotian Current waters were highly oxygenated due to low salinities and temperatures found there. Nitrate and dissolved

oxygen concentrations were inversely correlated, and nitrate levels generally increased with depth. Nitrite did not follow any trends with depth or season. Silicate concentrations were also variable in space and time. In general, nutrient concentrations were high, but intraregional variations were not defined.

Results suggested that while general meteorologic and oceanographic patterns may be discerned from archived data sources, accurate assessments require finer scale investigations of the individual parameters.

STUDY PRODUCT(S): Godshall, F. A., R. G. Williams, J. M. Bishop, F. Everdale, and S. W. Fehler. 1980. A Climatologic and Oceanographic Analysis of the Georges Bank Region of the Outer Continental Shelf. A final report by U.S. Department of Commerce, National Oceanic and Atmospheric Administration for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Contract No. AA551-IA8-14. 290 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic OCS Physical Oceanography Field Study, FY 1977.

REPORT TITLE: South Atlantic OCS Physical Oceanography Final Progress Report (First Year). Vol. I, Executive Summary; Vol. II, Technical Report; Vol. III, Data Products; Vol. IV, Books 1 and 2.

CONTRACT NUMBER(S): BLM: CT7-29; MMS: 14-12-0001-29133.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1977.

COMPLETION DATE OF REPORT: July 1979; February 1980; March 1980.

COST(S): FY 1977: \$1,318,729; Cumulative Project Cost: \$1,318,729.

PROJECT MANAGER(S): P. Debrule, E. Waddell.

AFFILIATION: Science Applications, Inc.

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PRINCIPAL INVESTIGATOR(S)*: P. Bedard, O. Brown, T. Curtin, T. Lee, L. Pietrafesa, D. Tung.

KEY WORDS: South Atlantic; Georgia Embayment; North Carolina; South Carolina; Georgia; Florida; physical oceanography; currents; shelf; Gulf Stream; hydrography; satellite imagery; transport; literature review; seasonality.

BACKGROUND: The Atlantic Outer Continental Shelf (OCS) of the United States has petroleum production potential. The prospect of OCS exploration and exploitation necessitates protecting the environmental integrity of the area. This responsibility came under the jurisdiction of the Bureau of Land Management (BLM). To provide information to aid in making management decisions, the BLM funded environmental studies in the South Atlantic Bight (SAB) OCS. Potential oil and gas activity brings with it the possibility of oil-related impacts (e.g., oil spills). To help protect against impacts, physical processes within the SAB OCS should be sufficiently understood to aid in predicting pathways of oil and gas related contaminants to sensitive biological areas.

OBJECTIVES: (1) To describe water circulation and mixing processes in the Georgia Embayment OCS and upper slope region.

DESCRIPTION: The report summarizes field work and analyses of physical oceanographic and meteorological data collected on the OCS from Cape Fear, North Carolina to Cape Canaveral, Florida during the period of September 1977 to November 1978. Data collection consisted of current meter measurements; hydrographic data acquisition (four seasonal cruises during 1978); and surface/near-surface current and hydrographic data collection at the area of turbid/clear water interface (7 through 14 August 1977, 30 April through 11 May 1978).

Two current meters were deployed off the Georgia coast in the vicinity of hydrographic transects of the BLM Benchmark Program. These short-term current meters recorded horizontal and vertical

current variability and temperature structures, and investigated wind effects and Gulf Stream related events (e.g., eddies). A long-term current meter was deployed to determine mean flow and extent of perturbations at near-surface, mid-water, and near-bottom depths.

Hydrographic measurements were taken along six onshore/offshore transects. Conductivity/temperature/depth (CTD) casts were made at each sampling station. A rosette multi-bottle array of Niskin bottles obtained water samples that were analyzed for nutrients (e.g., nitrate), dissolved oxygen, salinity, and chlorophyll *a*. Continuous thermosalinograph measurements were taken while in transit between stations. Satellite infrared imagery was used to document variability in the sea surface temperature in the SAB OCS. Imagery and data were obtained from the National Environmental Satellite Service for during April and November 1977. These data were compared with on-board data to determine confidence levels for infrared satellite mapping techniques.

The areas offshore from Hilton Head Island, Georgia and the mouth of the Savannah River were used to study transport of surface and near-surface borne materials along the turbid/clear water interface. Fluorescent dyes, aluminum powder, and sheets of paper were deployed along five transects to simulate surface pollutants. Their path along the surface was monitored by aerial photography.

Spatial and temporal descriptions of surface winds were achieved by analyzing reports collected by meteorological services. Observations reported from the area bounded by 25°N and 35°N Lat, 72°W Long, and the U.S. southeast coast were plotted for the time period from September 1977 to November 1978. Surface winds, wave/swell, and correlation between wind and sea state were analyzed.

A review of existing literature pertaining to the SAB OCS physical oceanography was given in the report. This report was the first of a three-year data acquisition and synthesis program designed to examine physical oceanography within the SAB OCS.

SIGNIFICANT CONCLUSIONS: Surface pollutants are influenced by both currents and winds. Movement is a weighted vector sum of the two forces. Vertical mixing and discharge plumes is common, however, the pycnocline inhibits complete vertical mixing. Tidal conditions are primary factors in plume behavior affecting convergence intensity, degree of vertical and lateral spreading, and intensity of density gradients. The data provide hydrographic information that was previously unavailable. Subsurface velocity data were not collected, therefore, quantitative evaluation of pollutant behavior could not be determined.

Gulf Stream events (e.g., eddies) appear to dictate temporal changes in flow and temperature near the shelf break. Long-term time series of the Gulf Stream western edge are essential to understanding Georgia Embayment frontal variability. Monitoring may be accomplished by satellite thermal imagery which gives accurate surface thermal maps. Continued collection of wind and wave data provides baseline information to establish statistical models of these processes and the probable effect on offshore structures.

STUDY RESULTS: Infrared satellite imagery can be used to determine fine and large scale differences in sea surface temperatures, as satellite data compared well with ground truth data taken from ships.

The Gulf Stream Western Boundary had large seasonal frontal variation. Largest onshore-offshore frontal variability in the southern part of the Georgia OCS occurred during spring, while largest variation in the northern section occurred during summer. Outer shelf current and temperature variability during summer were quite similar to winter conditions. Semidiurnal tides during summer were factors for total current variability and appear similar to tides during winter. Semidiurnal tides produced temperature changes with amplitudes of 2 to 5°C. Numerous current and temperature low-frequency fluctuations occur following northward and southward wind events. However, current and temperature changes occur that are not wind-related.

Numerous physical processes account for water movements. Synoptic and seasonal scale water motions are due to large-scale weather systems and/or seasonal variation in heat and salt input. Synoptic changes predominantly occur by cyclonic and anticyclonic wind field disturbances, while other low frequency current fluctuations are due to deep ocean movements. High frequency water movements occur due to diurnal tides, inertial oscillations, and sea breezes. Incursion of the Gulf Stream on the shelf at the long-term current meter station occurred three times during the study.

Water properties over the OCS and Blake Plateau are determined by seasonally energetic processes. Gulf Stream subsurface meanders can mix warm, saline water with shelf water or supply the shelf with cool, nutrient rich water depending on the season. Spring and early summer bring freshwater runoff which may reduce temperature and salinity near shore and cause local stratification. Seasons of northerly winds (i.e., spring, early summer) bring Virginia water transport that reduces temperature and salinity and accelerates freshwater exchange. Surface cooling during winter may cause shelf water to cascade off the shelf and slope. Shelf water, from the shelf break shoreward to the 20 m isobath, is a mixture of Gulf Stream water and fresher waters found nearshore. At the turbid/clear water interface, plume (surface currents) dynamics and associated convergent fronts were related to tidal movements and estuarine freshwater contribution. Surface tracer movements respond to wind drag and surface currents, accounting for occasional divergent trajectories of tracers.

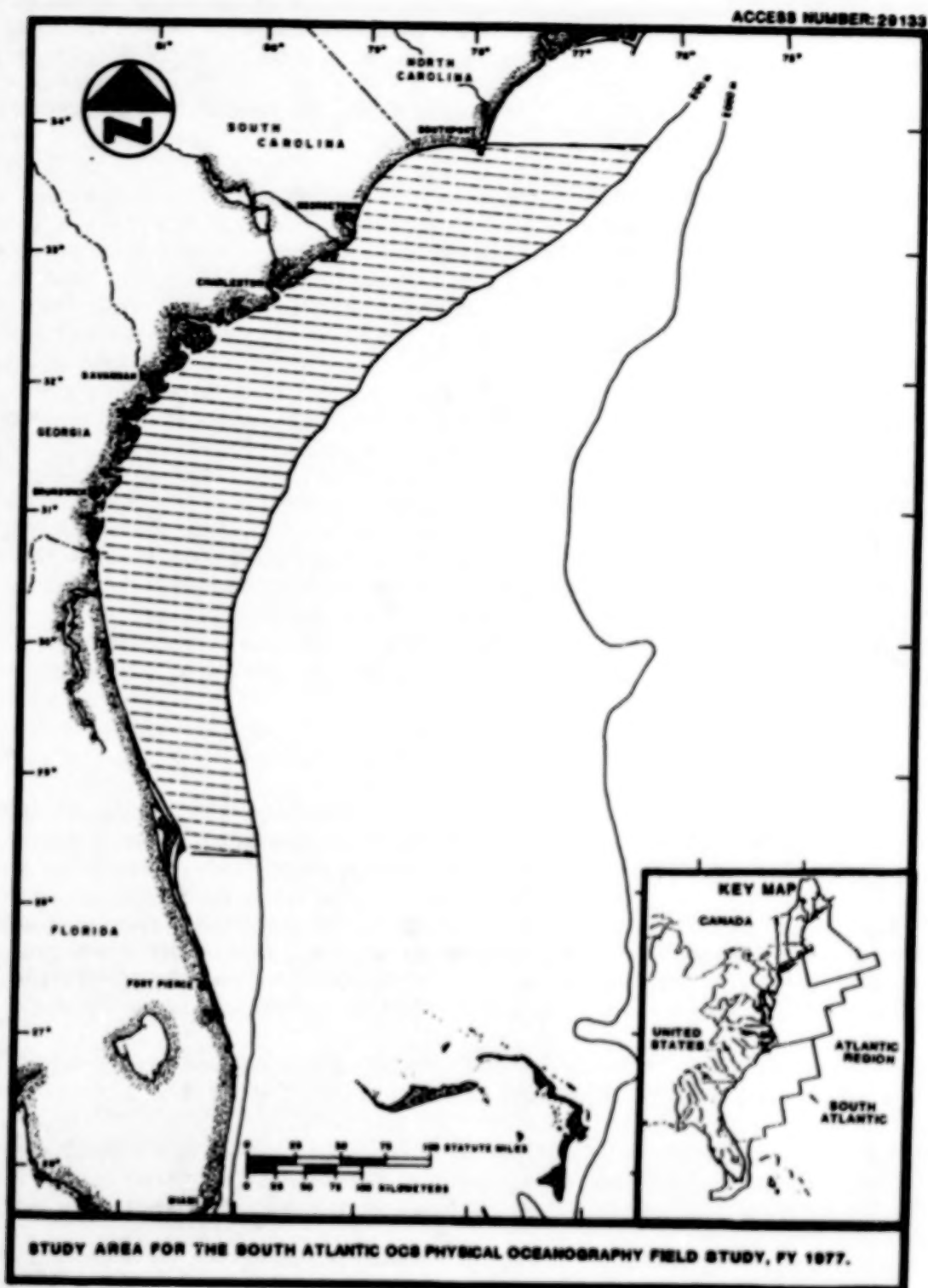
Hydrographic data showed that inter-water mass mixing occurred readily but intra-water mass mixing was inhibited by density gradients.

Wave/wind analysis showed both are generally from the same direction. Highest wave/wind conditions occurred during October 1977 in the northern part of the study area.

STUDY PRODUCT(S): Science Applications, Inc. 1980. South Atlantic OCS Physical Oceanography Final Progress Report (First Year). A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Vol. I (Executive Summary)-NTIS No. PB80181548; Vol. IV, Books 1 and 2. Contract No. 14-12-0001-29133. 12 pp. + 174 pp.

Science Applications, Inc. 1979. South Atlantic OCS Physical Oceanography Final Progress Report (First Year). A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Vol. II (Technical Report)-NTIS No. PB80181555; Vol. III (Data Products)-NTIS No. PB80181563. Contract No. 14-12-0001-29133. 326 pp. + 590 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: South Atlantic OCS Physical Oceanography, Year II.

REPORT TITLE: South Atlantic OCS Physical Oceanography Final Progress Report (Second Year).
Vol. I, Executive Summary; Vol. II, Technical Report; Vol. III, Data Products (Parts 1 and 2).

CONTRACT NUMBER(S): BLM: CT8-52; MMS: 14-12-0001-29138.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978; 1979.

COMPLETION DATE OF REPORT: January 1981.

COST(S): FY 1978: \$1,019,601; FY 1979: \$164,803; Cumulative Project Cost: \$1,184,404.

PROJECT MANAGER(S): E. Waddell.

AFFILIATION: Science Applications, Inc.

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PRINCIPAL INVESTIGATOR(S)*: L. Atkinson, P. Bedard, O. Brown, T. Curtin, P. Hamilton, T. Lee, L. Pietrafesa, E. Waddell.

KEY WORDS: South Atlantic; South Atlantic Bight; North Carolina; South Carolina; Georgia; Florida; physical oceanography; currents; shelf; Gulf Stream; hydrography; satellite imagery; transport; upwelling; wind; seasonality.

BACKGROUND: The Outer Continental Shelf (OCS) of the United States has great potential for petroleum production. Exploration and exploitation of OCS areas for oil necessitates maintenance of environmental integrity within these areas and coastal surroundings. One area of interest is the South Atlantic Bight (SAB) OCS, therefore, the Bureau of Land Management (BLM) initiated environmental studies in the SAB OCS to provide information for development and operational procedures and to help make appropriate management decisions. One aspect of the program involves the description and understanding of physical oceanographic mechanisms working within the SAB OCS, so possible movement of oil and gas related contaminants can be predicted.

OBJECTIVES: (1) To understand and document SAB OCS physical oceanography so the various processes can be parameterized and modeled.

DESCRIPTION: The reports present a summary of Year II of the multiyear SAB OCS physical oceanographic field study. Physical oceanographic and meteorological data were collected on the OCS from Cape Fear, North Carolina to Cape Canaveral, Florida during the period of November 1978 through February 1980.

This study involves the acquisition and analysis of data concerning subsurface and surface currents, thermal imagery, hydrography, and wind and water level. Subsurface currents were determined by long-term current meter arrays (3 current meters array). Surface currents were documented using radio bearing surface drifters. Shore based direction finders were placed so accurate drifter location could be determined by triangulation. There were three seasonal drifter deployments. Surface thermal variability of the Gulf Stream was obtained by satellite imagery, expendable bathythermographs, aircraft radiation thermometers, and Navy supplied weekly Gulf Stream frontal maps. Temperature data from ships and aircraft were used to check imagery data.

Hydrographic data were collected during four seasonal cruises. A total of 26 transects and 268 stations were sampled during the four cruises. Most transects and stations were repeated from one cruise to the next. Conductivity/temperature/depth (CTD) hydrocasts were made at most stations. A rosette multi-bottle array of Niskin bottles obtained water samples that were analyzed for nutrients (e.g., nitrate), dissolved oxygen, salinity, and chlorophyll *a*. Expendable bathythermographs were deployed at some stations. Near surface temperature and salinity were continuously monitored using a Plessey thermosalinograph.

Hourly sea levels were obtained from the National Ocean Survey (NOS). Coastal weather data were collected at various shore based stations and two weather buoys.

SIGNIFICANT CONCLUSIONS: Circulation of the SAB OCS is the result of winds, water level fluctuations, and Gulf Stream related events (e.g., eddies), all of which are closely interrelated. Zones along the shelf can be identified by the mechanisms controlling circulation; the outer shelf dominated by Gulf Stream events (e.g., meanders), and the mid-shelf and inner-shelf where tides and direct wind account for most current fluctuations. Current data support the hypothesis that shelf proper circulation may be explained by the Ekman equilibrium model.

Upwellings of nutrient rich water into the euphotic zone for biological uptake are predominantly caused by Gulf Stream events. Upwelling can result in locally high primary productivity and may be a more important nutrient source than continental runoff.

Surface currents within the Gulf Stream events have not been adequately explained. Further research is necessary to document circulation patterns (surface and subsurface currents) in areas of potential oil and gas leasing to allow proper impact assessment.

STUDY RESULTS: Winds occurring throughout the SAB are quite similar, however, wind speed often increases offshore. Wind seasonality showed predominant winter movement to the southeast, spring movement to the north, June-July movement to the west, and August movement to the east. Coastal wind measurements indicated significant diurnal peaks, which suggest the presence of a persistent sea breeze system.

Mid-shelf sea surface temperatures had expected seasonal cycles, however, large temperature fluctuations were present probably due to Gulf Stream related events.

The Gulf Stream Western Boundary (GSWB) had lateral movement which was documented over a 13-month period. GSWB variability mostly occurred over periods of less than a month.

Currents result from wind, tides, and Gulf Stream events, however, a lower salinity inshore water band caused by runoff may cause density driven circulation. These density gradients form barriers to onshore movement of Gulf Stream events. All current related factors considered, dominant current fluctuations were largest at the shelf break. Mid-shelf current fluctuations were predominantly the result of semidiurnal tidal currents.

Large amplitude current and temperature fluctuations occurred near the shelf break, probably due to meanders in the Gulf Stream. The periodicity of these fluctuations are strongly correlated with area winds, suggesting wind forces may be the mechanism for initiating meanders. Winds to the north caused offshore surface water transport, while winds to the south caused shoreward surface water transport and associated onshore movement of the GSWB.

Current meter data showed that eddies occurred on the average of one per week during spring. Eddy occurrence had changed since the average was one every two weeks for the first 11 months of data. Upwelling was caused predominantly by Gulf Stream meanders and eddies partly because of their relative frequency (every 2 to 12 days throughout the year).

Gulf Stream water had relatively little seasonal change except the fall-winter temperature decline. Shelf water showed a seasonal temperature cycle. Salinity and nutrient variations observed were due to a cumulative influence of several processes. The horizontal distribution of hydrographic variables was largely dependent on GSWB events (e.g., eddies).

Shelf topography affects Gulf Stream events. Gulf Stream deflection at specific geographical areas (i.e., "Charleston Bump") significantly reduces the frequency of Gulf Stream events and allows circulation to be more atmospherically dominated.

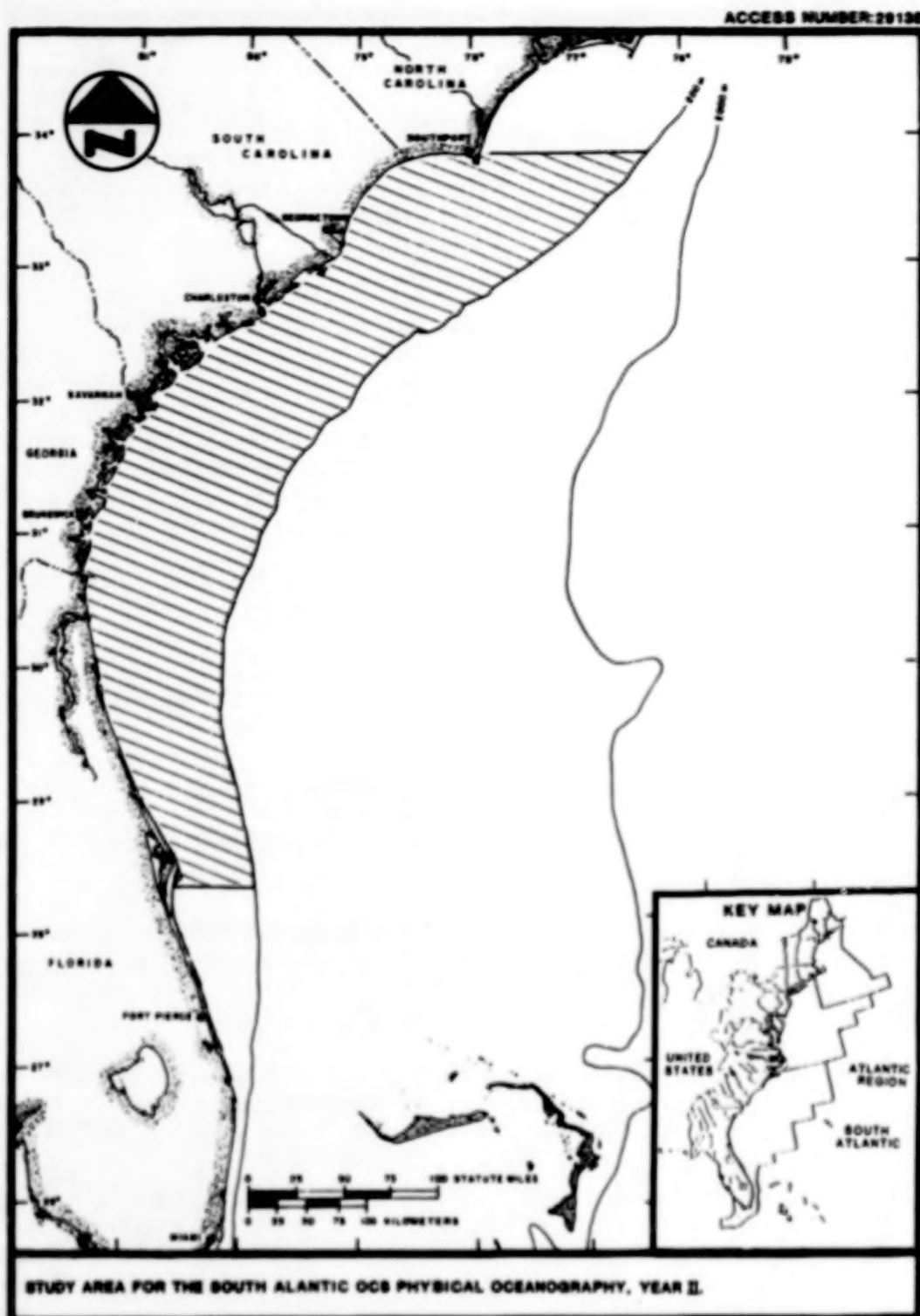
Results of surface current drifters showed inner-shelf and mid-shelf currents were predominantly wind driven and mid-shelf to outer-shelf currents were dominated by Gulf Stream events.

STUDY PRODUCT(S): Science Applications, Inc. 1981. South Atlantic OCS Physical Oceanography Final Progress Report (Second Year). Vol. I, Executive Summary. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB82141862. Contract No. 14-12-0001-29138. 14 pp.

Science Applications, Inc. 1981. South Atlantic OCS Physical Oceanography Final Progress Report (Second Year). Vol. II, Technical Report. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB82141870. Contract No. 14-12-0001-29138. 354 pp.

Science Applications, Inc. 1981. South Atlantic OCS Physical Oceanography Final Progress Report (Second Year). Vol. III, Data Products (Parts 1 and 2). A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS Nos. PB82141888 (Part 1) and PB82141896 (Part 2). Contract No. 14-12-0001-29138. 1,102 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Application of a Coastal Circulation Model to the South Atlantic Outer Continental Shelf.

REPORT TITLE: South Atlantic Bight Numerical Model Application--Executive Summary; A Diagnostic Technique for Deducing the Climatological Circulation as Applied to the South Atlantic Bight; The Physical Oceanographic and Sea Surface Flux Climatology of the South Atlantic Bight; Circulation Studies in the South Atlantic Bight with Prognostic and Diagnostic Numerical Models.

CONTRACT NUMBER(S): BLM: CT9-32; MMS: 14-12-0001-29170.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1979.

COMPLETION DATE OF REPORT: September 1981.

COST: FY 1979: \$407,922; Cumulative Project Cost: \$407,922.

PROJECT MANAGER(S): H. Herring.

AFFILIATION: Dynalysis of Princeton.

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PRINCIPAL INVESTIGATOR(S)*: A. Blumberg, H. Herring, L. Kantha, G. Mellor.

KEY WORDS: South Atlantic; South Atlantic Bight; physical oceanography; modeling; transport; currents.

BACKGROUND: Circulation dynamics affect potential contaminant transport associated with offshore activities. Forecasting and hindcasting numerical models can accurately simulate circulation patterns in a cost-efficient manner. The U.S. Department of the Interior supported a numerical model analysis of South Atlantic Bight circulation patterns to develop effective management schemes.

OBJECTIVES: (1) To characterize water mass circulation in the South Atlantic Bight using numerical models and archived data; and (2) To determine the models ability to predict fates of oceanic pollutants.

DESCRIPTION: The area of concern for the numerical modeling effort of the South Atlantic Bight was between 27 and 37°N lat and the 73°W long. The first numerical model used was the time dependent general circulation model (GCM). This was a three-dimensional model including advection, horizontal diffusion, and bottom friction formulation. Turbulent mixing and closure

techniques allowed simulation of the upper oceanic mixed layer. Wind density and forcing, storm surge, and tidal effects were incorporated into the model. The model was used in diagnostic mode and prognostic mode. Climatological density fields from historical data were input for model initialization. Open boundary conditions for the GCM were provided by another model. The characteristic tracing model (CTM-81) used wind and bottom stresses in geostrophic equations of motion (including shear stress terms). Transport and currents were deduced by this model for the boundaries and the entire region using wind stress fields. The CTM-81 was used only in diagnostic mode. Climatological data for input to the models were obtained from archived data at the National Oceanographic Data Center and National Climatic Center. Additional data were provided by the Skidaway Institute of Oceanography. An atlas of oceanographic and sea surface flux climatology for the South Atlantic Bight was compiled. Results of simulations were presented as map plots of circulation patterns following various parameter changes to the models.

SIGNIFICANT CONCLUSIONS: Comparisons between models and observational data indicated that both models were accurate. The CTM-81 was best suited for generating long-term averages of oceanic currents and hence useful in seasonal pollution transport models. Particular pollution events are better modeled by the GCM which provides dynamically evolving currents. Both models were useful for areas which lack sufficient observational data.

STUDY RESULTS: The CTM-81 supplied open ocean boundary conditions for the GCM and diagnostically deduced transports and currents in the water column from the prescribed hydrographic and surface wind data. Results from the CTM-81 depicted well the climatological Gulf Stream and associated circulation. For purposes of providing input to U.S. Geological Survey oil spill trajectories, the climatological background currents generated by the model could be used along with 3.5% rule. Sensitivity experiments revealed that a southern transect crossing the Florida Straits would be the best location to obtain supportive current flow data needed to improve model accuracy. Limitations of the CTM-81 were the inability to incorporate bottom stress terms in the potential planetary vorticity equation and the generally simplified physics involved with it.

Circulation predictions using the GCM were realistic in most cases; however, diagnostic runs produced a broader, less energetic Gulf Stream when density fields were varied. Prognostically run, the density field was allowed to evolve dynamically in accordance with model specifications depicting a more realistic Gulf Stream. Documented variations in Gulf Stream path, such as deflection by the Charleston Hump, were also shown by prognostic runs. Diagnostic simulations produced smaller deflections and generally noisier circulation patterns. Currents in the vicinity of Cape Hatteras did not indicate sufficient inflow of cold water from the Middle Atlantic Bight; this unrealistic feature was due to resolution problems across the northern boundary. Flow on the shelf was generally an Ekman response to wind forcing although some topographically induced cyclonic circulations were established. On the shelf south of Jacksonville, Florida, there was a persistent cyclonic feature exhibiting southward flow along the coast. Deep flows tended to follow planetary vorticity contours with a distinct Western Boundary Undercurrent. The Western Boundary Undercurrent entered through the northern boundary and flowed to 34°N lat before its signal was lost.

STUDY PRODUCT(S): Blumberg, A. F., H. J. Herring, L. H. Kantha, and G. L. Mellor. 1981. South Atlantic Bight Numerical Model Application--Executive Summary. A final report by Dynalysis of Princeton for the U.S. Department of the Interior, Bureau of Land Management, Atlantic OCS Office, New York, NY. NTIS No. PB83143297. Contract No. AA551-CT9-32. 32 pp.

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Kantha, L. H., A. F. Blumberg, and G. L. Mellor. 1981. A Diagnostic Technique for Deducing the Climatological Circulation as Applied to the South Atlantic Bight. A final report by Dynalysis of Princeton for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB3143263. Contract No. AA551-CT9-32. 124 pp.

Kantha, L. H. 1980. A Diagnostic Ray-Tracing Scheme for Deducing the Climatological Current Distribution in the South Atlantic Bight. Dynalysis Report No. 64.

Kantha, L. H., A. F. Blumberg, H. J. Herring, and G. L. Mellor. 1981. The Physical Oceanographic and Sea Surface Flux Climatology of the South Atlantic Bight. A final report by Dynalysis of Princeton for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB3143271. Contract No. AA551-CT9-32. 142 pp.

Blumberg, A. F. and G. L. Mellor. 1981. Circulation Studies in the South Atlantic Bight with Prognostic and Diagnostic Numerical Models. A final report by Dynalysis of Princeton for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB3143289. Contract No. AA551-CT9-32. 104 pp.

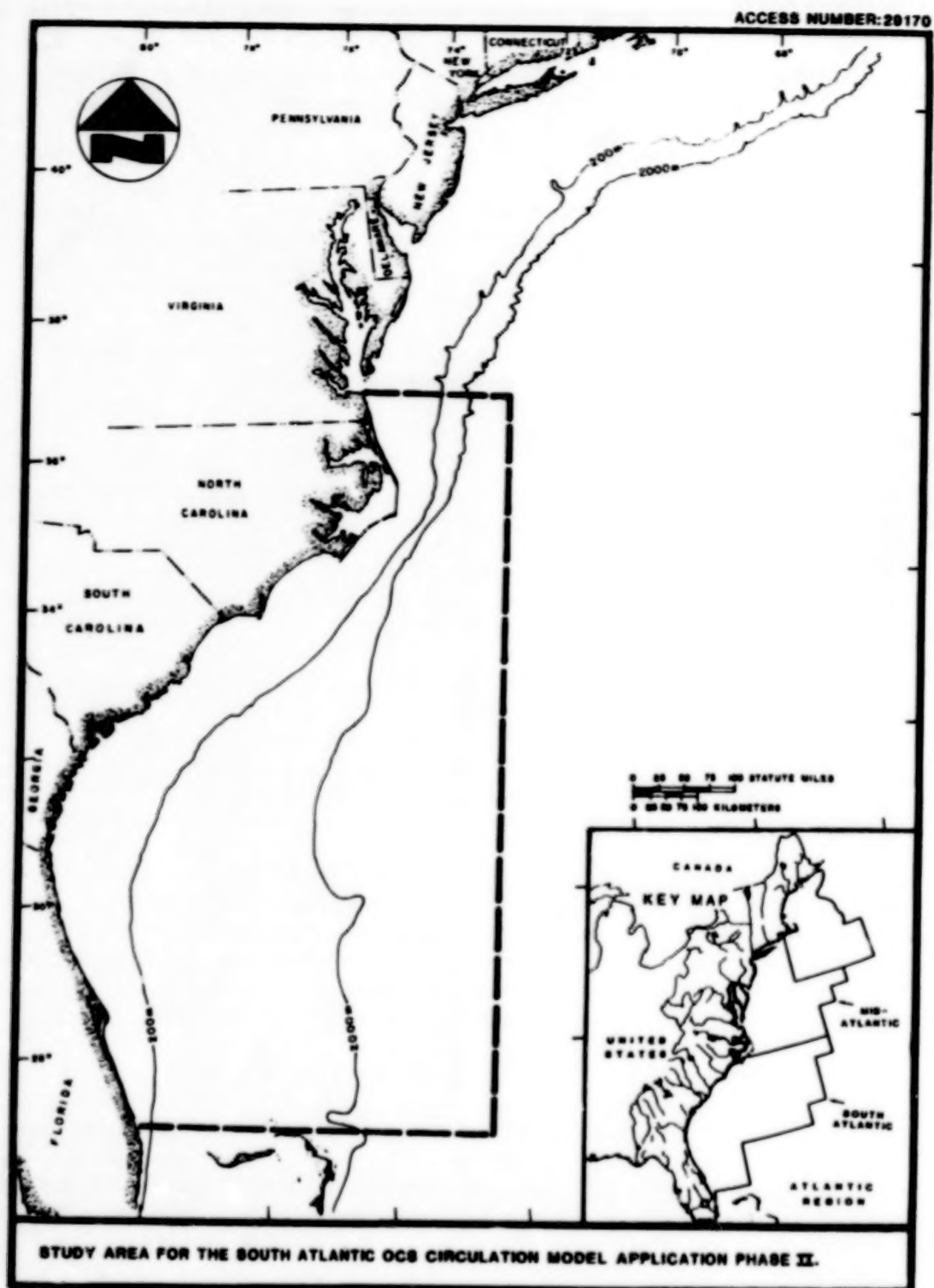
Blumberg, A. F. and G. L. Mellor, 1983. A description of a three-dimensional coastal ocean circulation model. In: N. Heaps (ed.), Three-Dimensional Shelf Models, Coastal and Estuarine Sciences, American Geophysical Union, Vol. 5.

Blumberg, A. F. and G. L. Mellor, 1983. Diagnostic and prognostic numerical circulation studies of the South Atlantic Bight. J. Geophys. Res. 88:4579-4592.

Kantha, L. H., G. L. Mellor, and A. F. Blumberg, 1981. Diagnostic calculations of the circulation in the Middle and South Bights. Ocean Modeling 37:5-11.

Kantha, L. H., G. L. Mellor, and A. F. Blumberg, 1982. A diagnostic calculation of the general circulation in the South Atlantic Bight. J. Phys. Oceanogr. 12:805-819.

**PI.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Blake Plateau Bottom and Mid-Water Current Study.

REPORT TITLE: Blake Plateau: Mid-Depth and Bottom Current Measurements.

CONTRACT NUMBER(S): BLM: CT0-35; MMS: 14-12-0001-29176.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1980.

COMPLETION DATE OF REPORT: September 1982.

COST(S): FY 1980: \$359,319; Cumulative Project Cost: \$359,319.

PROJECT MANAGER(S): C. Casagrande.

AFFILIATION: General Oceanics, Inc.

ADDRESS: 1295 N.W. 163rd Street, Miami, Florida 33169.

PRINCIPAL INVESTIGATOR(S)*: P. Bedard, C. Casagrande, R. Cook, J. Karpen, T. Lee, S. Niskin, E. Waddell, R. Watts.

KEY WORDS: South Atlantic; Blake Plateau; physical oceanography; Gulf Stream; currents; shelf.

BACKGROUND: The Blake Plateau is located seaward of the South Atlantic Bight Outer Continental Shelf (OCS) and has potential for oil and gas production. To secure information for predicting and assessing environmental consequences of developmental activities, the U.S. Department of the Interior initiated studies on Blake Plateau oceanographic processes. This report contains results of a 13-month study of current and temperature variability at 30°N lat over the Plateau.

OBJECTIVES: (1) To establish a physical oceanographic data base from which important Blake Plateau processes may be identified and predictive models can be developed and tested.

DESCRIPTION: Currents and temperatures were measured along 30°N lat with a cross-stream array of five subsurface current meter moorings extending from the shelf edge (80°15'W long) to the Blake Plateau escarpment (77°W long). Mooring A had a single current meter 3 m above bottom on the 75-m isobath of the shelf edge. Moorings B and C had current meters located at depths of 400, 600, and 797 m. Mooring B was near the subsurface extension of the Gulf Stream. Mooring C was near the seaward margin of the Gulf Stream. Moorings D and E had current meters positioned 3 m above bottom at depths of about 800 and 970 m, respectively. The easternmost mooring (E) was located near the seaward extension of the Blake Plateau on the Blake Spur.

Model 6011 Niskin winged current meters were used. Each meter was equipped with a tilt sensor, effect sensors, and a thermistor. Instrument signals were recorded in binary code on magnetic tape cassettes for subsequent computer analyses. Reduced data consisted of velocity and temperature time series. Each velocity time series was decomposed into orthogonal components (east-west, north-south), demeaned, and progressively filtered with 3- and 40-h low pass filters. The 40-h low pass filter removed tidal and inertial motions from the velocity record. Data products included: plots

of time series, stick plots of filtered data, spectra of filtered data, progressive vector diagrams, biweekly and total means, and data tapes.

SIGNIFICANT CONCLUSIONS: Data from the three nearshore moorings provided information on Gulf Stream behavior. A strong northerly component was confirmed but periodic east-west meanderings were responsible for most observed variation in flow and temperature. East of the Gulf Stream, the two offshore moorings disclosed prolonged southward flow in near bottom currents which were not correlated with Gulf Stream activity.

STUDY RESULTS: Current and temperature fluctuations occurred over a period band of 2 to 14 days at all locations and were the result of east-west meanderings of the Gulf Stream. Flow changes on the cyclonic side of the Gulf Stream generally displayed cyclonic rotation while the anticyclonic side displayed anticyclonic flows which were 180° out of phase with flow variations on the cyclonic side. Offshore meanders were characterized by offshore flow and decreasing temperature on both sides of the axis; there was increasing downstream flow in the anticyclonic shear zone, and decreasing downstream flow in the cyclonic shear zone. For inshore meanders, flow and temperature were correlated with increasing downstream flow in the cyclonic zone and decreasing downstream flow in the anticyclonic shear region. Flow variability near bottom at the shelf break was apparently caused by Gulf Stream meanders. Another similar scenario was found: cold, cyclonic perturbations occur during offshore meanders while onshore meanders display northward flows and increased temperatures.

Gulf Stream meanders appear to be caused by waves traveling north at 30 to 70 cm s⁻¹ with wave lengths of 100 to 200 km and periods of several days to one week. Redistribution of kinetic and potential energy between fluctuations and mean flow may cause these waves to be unstable, resulting in perturbations.

East of the Gulf Stream, near-bottom currents exhibited prolonged southward flows for up to 42 days with speeds greater than 30 cm s⁻¹. These events were not explained by Gulf Stream meanderings. Southward undercurrents from Cape Hatteras and cyclonic, cold core eddies may contribute to the events, but additional data are necessary to confirm or refute these hypotheses. Near the Gulf Stream axis at 400 m, mean flows were northward at 60 to 75 cm s⁻¹ with maximum downstream current being 109 cm s⁻¹. Mean vertical shear at this location was approximately -2×10^{-3} s⁻¹. Mean volume transport through the mooring arrays was 4×10^6 m³ s⁻¹ and represented 10% of the total transport observed at 30°N lat. A seasonal maximum transport of 33.6×10^6 m³ s⁻¹ was recorded during early summer and a minimum of 25.4×10^6 m³ s⁻¹ was found during December. Changes in the barotropic component of flow are responsible for observed differences in volume transport.

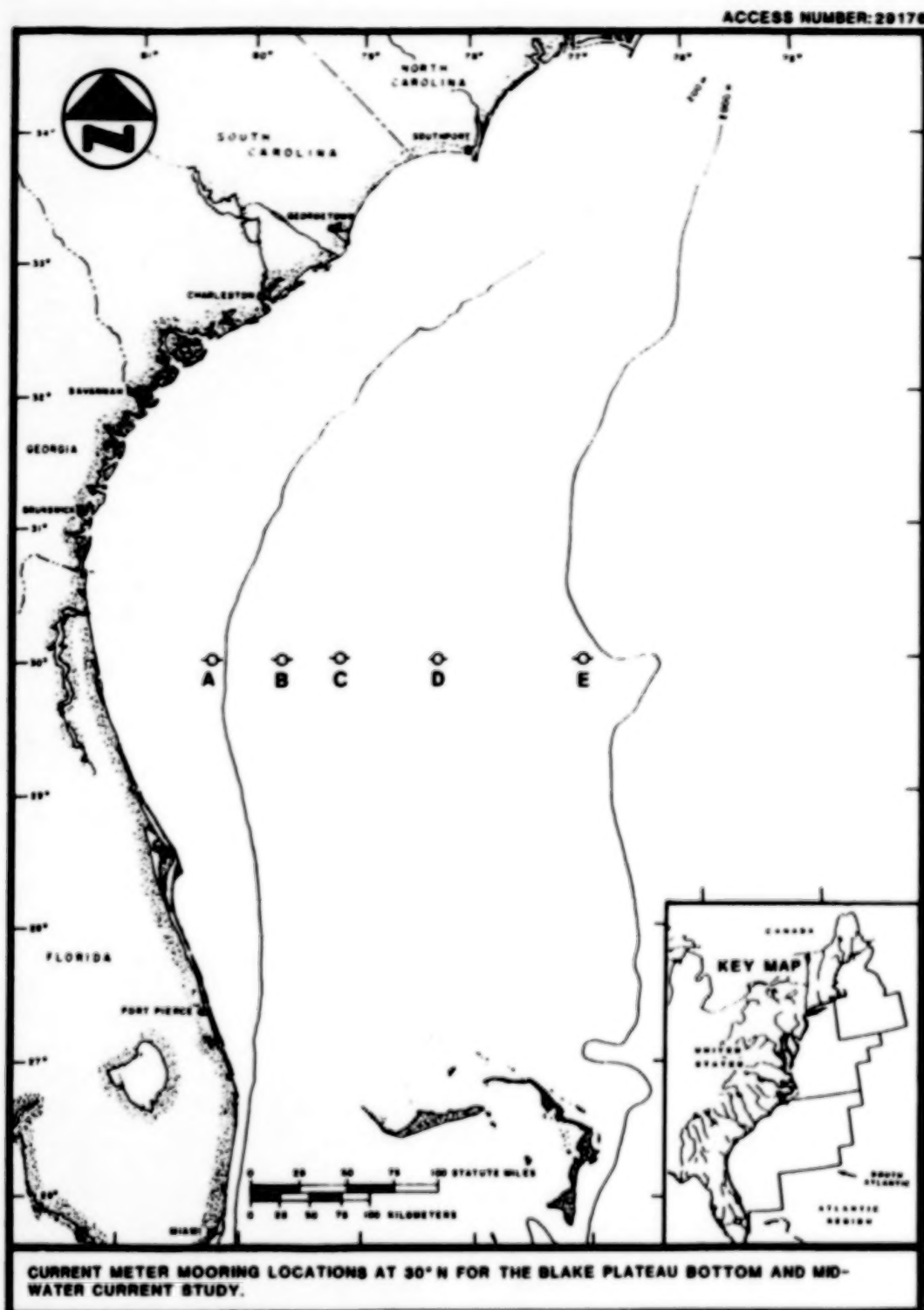
STUDY PRODUCT(S): Casagrande, C. 1982. Blake Plateau: Mid-Depth and Bottom Current Measurements. A final report by General Oceanics, Inc. for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. NTIS No. PB83144519. Contract No. AA851-CT0-35. 168 pp.

Lee, T. N. and E. Waddell. 1982. On Gulf Stream variability at 30°N. In: Proceedings, Workshop on Gulf Stream Structure and Variability, The Office of Naval Research, Research Triangle, NC, April 1982, pp. 223-253.

Access Number: 29176

Lee, T. N. and E. Waddell. 1983. On Gulf Stream variability and meanders over the Blake Plateau at 30°N. J. Geophys. Res. 88: 4617-4631.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Blake Plateau, Bottom and Mid-Water Current Study, Year 2.

REPORT TITLE: Blake Plateau: Near Bottom Current/Temperature Measurements on 36°N.

CONTRACT NUMBER(S): BLM: CT1-33; MMS: 14-12-0001-29187.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1981.

COMPLETION DATE OF REPORT: March 1983.

COST(S): FY 1981: \$383,851; Cumulative Project Cost: \$383,851.

PROJECT MANAGER(S): C. Casagrande.

AFFILIATION: General Oceanics, Inc.

ADDRESS: 1295 N.W. 163rd Street, Miami, Florida 33169.

PRINCIPAL INVESTIGATOR(S)*: P. Bedard, C. Casagrande, J. Karpen, T. Lee, S. Niskin, E. Waddell, R. Watts.

KEY WORDS: South Atlantic; Blake Plateau; physical oceanography; shelf; slope; Western Boundary Undercurrent; Gulf Stream.

BACKGROUND: Blake Plateau is an area of potential oil and gas exploration. To fill oceanographic data gaps, the U.S. Department of the Interior funded two long-term studies of current and temperature variability in the area. This report represents the results of the second year of data collected from 36°N Lat.

OBJECTIVES: (1) To provide long-term, area-wide data on Blake Plateau oceanographic processes for use in developing and testing predictive models; and (2) To characterize the Western Boundary Undercurrent.

DESCRIPTION: Currents and temperatures were measured with a cross-stream array of five subsurface taut-wire current meter moorings. The array extended from the shelf edge (74°55'V long) east to 73°01'W long. Moorings were in place from 11 May 1981 to 9 June 1982, with partial mooring changes during November 1981 and February 1982. Mooring F was at the Outer Continental Shelf (OCS) edge and deployed at the 77-m isobath with current meters 28 and 34 m above the bottom. Moorings G, H, I, and J were across the continental slope, had current meters 103 and 111 m above bottom, and were in water depths of 1,600, 2,277, 3,086, and 3,700 m, respectively. Sites were selected to span the Western Boundary Undercurrent.

Model 6011 Niskin winged current meters were used. Each meter was equipped with a tilt sensor, effect sensors, and thermistor. Signals from instruments were recorded in binary code and stored on magnetic tape for subsequent computer analyses. Reduced data consisted of velocity and temperature time series. Each velocity series was decomposed into orthogonal components (E-W, N-S), demeaned, and progressively filtered with 3- and 40-h low pass filters. The 40-h low pass filter

Access Number: 29187

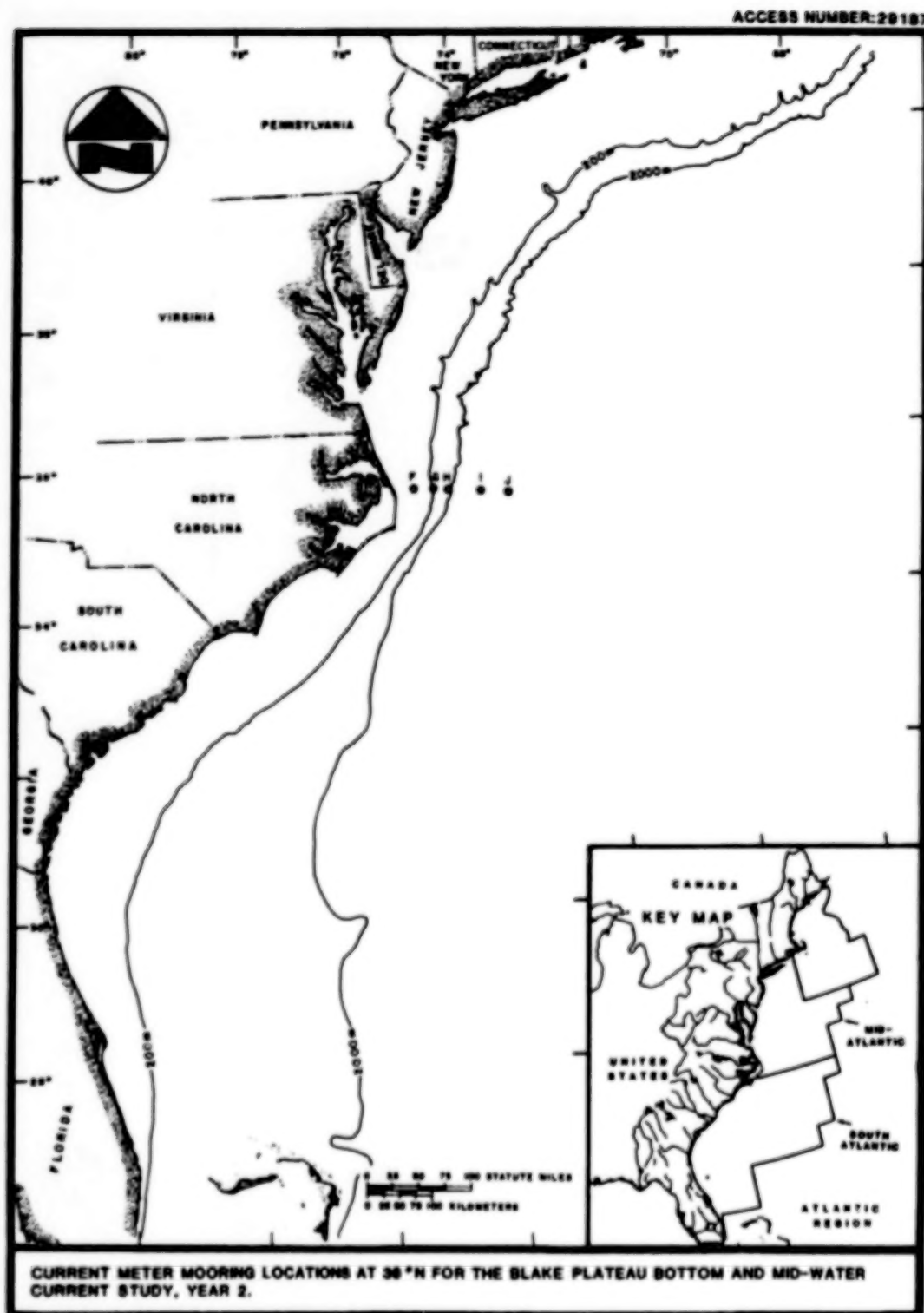
removed tidal and inertial motions from velocity records. Data products included plots of time series, stick plots, spectra of filtered current components, biweekly and total means, and data tapes.

SIGNIFICANT CONCLUSIONS: Near-bottom mean flow and variability in the Western Boundary Undercurrent were described from current meter data. There was a mean southward flow at the shelf break, Mooring F. Moorings G, H, and I were all within the Western Boundary Undercurrent, with the strongest southward flow at Mooring H. Mooring J was east of the Western Boundary Undercurrent. Much of the observed variability between Moorings I and J was due to lateral meanders of the Gulf Stream.

STUDY RESULTS: Near-bottom mean flow at the shelf edge Mooring F was 2 to 5 cm s⁻¹. Considerable variability recorded was attributed to storms which increased velocities to 40 cm s⁻¹. Mean flow was directed southward and aligned with bathymetric contours. Mean flow at Moorings G, H, and I was southward with flow rates of 2.2, 11.5, and 5.1 cm s⁻¹, respectively. These moorings were in the Western Boundary Undercurrent. Mooring I represented the offshore boundary of the Western Boundary Undercurrent. The Western Boundary Undercurrent shifted either shoreward leaving Mooring I in warmer waters of weaker, variable flow, or offshore in colder waters with a stronger southward flow. The seaward Mooring J, was not in the Western Boundary Undercurrent and exhibited periods of northeastward, southwestward, or northwestward flow with no long-term mean flow. Major changes at the current meter sites, especially Moorings I and J, were due to Gulf Stream meanders. A narrow region of northeastward flow that occurred beneath the Gulf Stream extended to the ocean floor; the boundary between this and the Western Boundary Undercurrent was usually between Moorings I and J. Lateral shifts in the near-surface Gulf Stream path resulted in temperature and flow changes at Mooring I. Current and temperature fluctuations between Moorings G, H, I and J may have been caused by Gulf Stream meanders and in some cases baroclinic topographic Rossby waves.

STUDY PRODUCT(S): Casagrande, C. E. 1983. Blake Plateau: Near Bottom Current/ Temperature Measurements on 36°N. A final report by General Oceanics, Inc. for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB83205047. Contract No. AA851-CT1-33. 87 pp. + app.

**PI.'s affiliation may be different than that listed for Project Manager(s).*



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STUDY TITLE: Interpretation of Physical Conditions and Their Application to Pollutant Transfer and Biological Resource Modeling.

REPORT TITLE: Interpretation of the Physical Oceanography of Georges Bank.

CONTRACT NUMBER(S): BLM: CT1-39; MMS: 14-12-0001-29188.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): North Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1981.

COMPLETION DATE OF REPORT: July 1982.

COST(S): FY 1981: \$824,414; Cumulative Project Cost: \$824,414.

PROJECT MANAGER(S): R. Scarlet.

AFFILIATION: EG&G Environmental Consultants.

ADDRESS: 300 Bear Hill Road, Waltham, Massachusetts 02254.

PRINCIPAL INVESTIGATOR(S)*: W. Brown, J. Cura, C. Flagg, D. Frye, R. Halliwell, J. Irish, B. Magnell, G. Mariani, S. McDowell, C. Mooers, N. Pettigrew, R. Scarlet, M. Spaulding, C. Swanson, W. Wright.

KEY WORDS: North Atlantic; Georges Bank; physical oceanography; modeling; currents; hydrography; seasonality; gyre; transport; flushing; satellite tracking; nutrients.

BACKGROUND: The New England Outer Continental Shelf (OCS) Physical Oceanography (NEOCSP) Program began in 1976 as part of the Bureau of Land Management's plan for managing offshore oil and gas exploration and development. The program was intended to provide data on transport and dispersion processes for management decisions concerning materials discharged or spilled on Georges Bank, how fast they disperse, where they go, and how long they remain in the area. The studies were also designed to describe the general temperature, salinity, and current patterns of the area, and to support interpretation of biological features by identifying nutrient sources and regions capable of high biological productivity.

OBJECTIVES: (1) To develop and refine concepts of the transport, dilution, and dispersion processes acting on the New England OCS; (2) To qualify and quantify the various transport processes such that the fate of OCS oil and gas related discharges released on Georges Bank can be described; (3) To develop a conceptual model (box model) of the mean circulation on Georges Bank with a quantitative description of the variability of the circulation and the exchange rates which

dominate the movement of pollutants and nutrients; and (4) To identify source regions for nutrients, geographic areas of high productivity, and establish residence times on Georges Bank.

DESCRIPTION: Major field measurements were performed in the New England OCS area from 1977 to 1979. During this period, a vast amount of data were collected from current meter moorings, bottom-mounted and coastal pressure gauges, hydrographic surveys, and biological sampling cruises. Some measurements of plankton species and plankton primary productivity were included in the field surveys. In addition to the NEOCSPO Program, data from the U.S. Geological Survey at Woods Hole, the Nantucket Shoals Flux Experiment, the Larval Patch Study, the National Marine Fisheries Service (NMFS) Northeast Channel Study, NMFS cruises, the National Oceanographic and Data Center archives from 1975 to 1979, and recent published literature were used in compiling the report.

SIGNIFICANT CONCLUSIONS: The physical oceanography of Georges Bank is characterized by the presence of a gyre whose currents move in a clockwise direction. Seasonal differences in the current speed and gyre were noted. Detailed seasonal and annual average maps of current structure and hydrography in and around Georges Bank were presented. Residence time for water on Georges Bank, based on drogue and current meter measurements, was consistent with the box model flow for the New England OCS, and ranged from 40 to 80 days. Drogue residence time in summer was 66 days vs. 45 days in winter. The difference was attributed to increased closure of the gyre circulation in summer.

STUDY RESULTS: The Georges Bank gyre consists of clockwise currents flowing around the Bank. The gyre is more intense and closed in summer than in winter. A closed gyre suggests that contaminants in the water column could be trapped around the bank.

In winter, a narrow current (about 20 km wide), called a jet, flows eastward along the north margin of the bank at approximately the 80-m isobath. The jet originates in an area north and east of Great South Channel and derives its initial water from the Wilkinson Basin. Currents in this jet average 18 cm s^{-1} near the surface and 7 cm s^{-1} at 80 m depth. Most of the water in this jet circulates completely around to the western portion of the bank. The eastward jet turns southward as it flows across the Northeast Peak. The current becomes broader as it proceeds clockwise to become a westward-flowing stream on the south side of the bank. Along the bank's south side, this current averages 12 cm s^{-1} on the surface and 3 cm s^{-1} in 85 m of water. As the flow proceeds westward, most of the water passes south of the Great South Channel and proceeds toward the New York Bight. Only 25% of the flow recirculates into Great South Channel and rejoins the northern jet.

In summer, currents in the gyre increase in speed starting on the north side (42 cm s^{-1} at surface; 21 cm s^{-1} at 80 m). The current in the Great South Channel increases both in speed and cross-sectional volume. Thus, the proportion of westward-flowing water along the south of the bank that turns north through the channel increases, reaching a maximum of 65% during late July. The Gulf of Maine and the waters of Georges Bank are thermally stratified due to summer heating and the surface water has become distinct from the intermediate depth water. Water from the jet which continues to flow onto the bank is drawn increasingly from surface waters, rather than from a mix of surface and intermediate waters.

For construction of the box model, transports were calculated through vertical sections around Georges Bank, past Cape Sable-Browns Bank, through the Nantucket Flux array, and through the

Northeast Channel. Flux estimates were assembled in two stages. The first stage addressed the balance, on a large scale, of the annual averaged transports of mass and salt. The second stage used the newly available current data to improve detail in the model. Results indicated a shelf water system driven by two major inputs: (1) water from the Scotian Shelf (52%) and (2) water from the Northeast Channel (43%). Outflow was primarily along the shelf south of Cape Cod (48%) and water displacement offshore by the shelf/slope front eddies (37%). The annual mass flux rate was $748 \times 10^3 \text{ m}^3 \text{ s}^{-1}$, representing a flushing time of 280 days for the whole region. The flushing rate was clearly seasonally dependent. In winter, the flushing rate dropped to 256 days, while in summer it rose to 305 days.

Satellite-tracked drogue trajectories were examined to estimate the impact of Gulf Stream eddies and meanders on the New England OCS. Using estimates of the horizontal and vertical dimensions of entrainment filaments, transport of water in these filaments was computed to be $46 \text{ km}^3 \text{ day}^{-1}$ ($0.53 \times 10^6 \text{ m}^3 \text{ s}^{-1}$). This represents a daily volume of water entrained in one observed eddy of 1.3% of the water volume of Georges Bank. Drogues were reported to occasionally move off the bank and around an eddy at a rate of 44 km day^{-1} (50 cm s^{-1}). If the recorded figures are realistic, cross-frontal mixing induced by Gulf Stream eddies may dominate all other mixing processes.

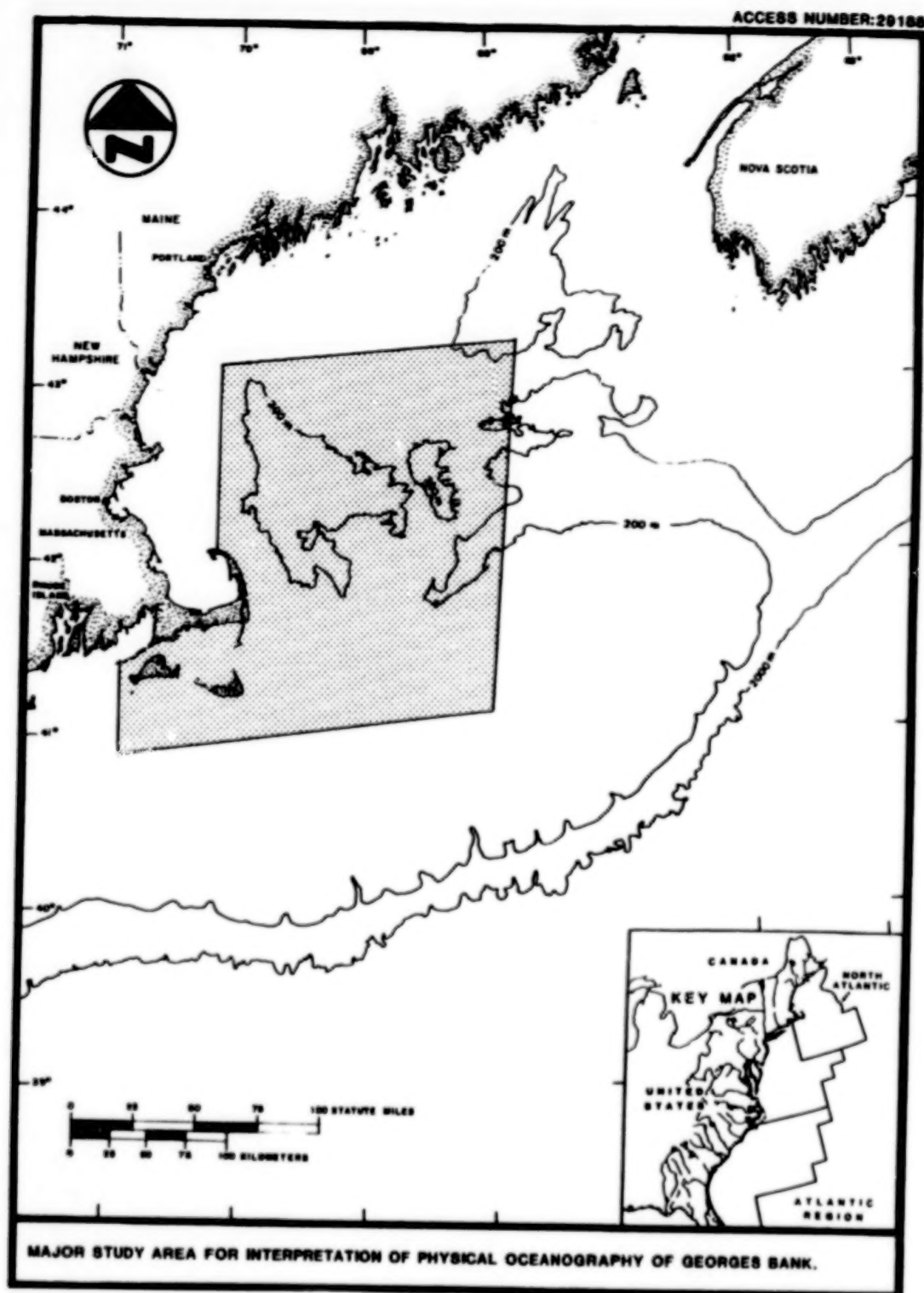
Major nutrient sources on Georges Bank are considered to be Gulf of Maine Surface Water and Maine Intermediate Water. The physical processes involved in nutrient transfer from the Gulf of Maine to the bank include horizontal advection across and vertical mixing at the north edge of the bank, as well as occasional upwelling onto the bank or into the Great South Channel current jet. This study showed a close spatial correlation between measures of mixing history (T/S group) and planktonic species assemblages. Species succession during annual growth cycles remains fairly constant from year-to-year in and around Georges Bank.

Data from NEOCSPO cruises showed that the "cold band" off Georges Bank is totally replenished every 30 to 60 days. This short flushing time requires a substantial source of cold, low salinity water. Detailed examination of NEOCSPO data showed four sources for the water in the cold band: (1) the central region of Georges Bank; (2) near surface in the Gulf of Maine; (3) mid-depth along the bank's north flank; and (4) from 100 to 150 m deep in the Northeast Channel. These waters become mixed at the Northeast Peak to form the cold band. The migration of the deep Northeast Channel water is important because it provides a pathway for nutrient-rich cold deepwater to reach the biological communities of the bank.

The assumption of geostrophic dynamics yields qualitatively reasonable results when compared to the measured quantities. Calculated baroclinic flow fields confirm the expected major features of mean circulation on Georges Bank.

STUDY PRODUCT(S): Flagg, C. N., B. A. Magnell, D. Frye, J. J. Cura, S. E. McDowell, and R. I. Scarlet. 1982. Interpretation of the Physical Oceanography of Georges Bank. A final report by EG&G Environmental Consultants for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Vol. I - NTIS No. PB83-149054; Vol. II - NTIS No. PB83-149062. Contract No. AA851-CT1-39. 840 pp.

**Pl.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Synthesis of South Atlantic Physical Oceanography Program Information.

REPORT TITLE: South Atlantic Physical Oceanography Study Final Report, Year Five. Vol. I, Executive Summary; Vol. II, Technical Report.

CONTRACT NUMBER(S): BLM: CT2-61; MMS: 14-12-0001-29201.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982.

COMPLETION DATE OF REPORT: February 1984.

COST(S): FY 1982: \$423,755; Cumulative Project Cost: \$423,755.

PROJECT MANAGER(S): E. Waddell.

AFFILIATION: Science Applications, Inc.

ADDRESS: 4900 Water's Edge Drive, Suite 255, Raleigh, North Carolina 29606.

PRINCIPAL INVESTIGATOR(S)*: L. Atkinson, O. Brown, T. Curtin, P. Hamilton, T. Lee, L. Pietrafesa, E. Waddell, R. Weisberg.

KEY WORDS: South Atlantic; Florida; Georgia; South Carolina; North Carolina; South Atlantic Bight; physical oceanography; synthesis; Gulf Stream; satellite imagery; wind; hydrography; currents; shelf; Georgia Embayment; Blake Plateau; eddy; seasonality; wind forcing; tidal currents.

BACKGROUND: The U.S. Department of the Interior (USDOI), interested in characterizing circulation patterns of the South Atlantic Bight, initiated the South Atlantic Physical Oceanography Study. This effort sought to describe prevailing circulation patterns and their underlying forcing mechanisms. The study program began in 1977 and synthesized information from other South Atlantic Bight oceanographic research projects. This information will aid USDOI management personnel in making decisions regarding Outer Continental Shelf lands to be leased for oil and gas exploration.

OBJECTIVES: (1) To examine and understand the influence of tides, winds, water mass density and the Gulf Stream on South Atlantic Bight circulation patterns; and (2) To document and explain the spatial and temporal variability of South Atlantic Bight hydrographic conditions such as temperature, salinity, density, dissolved oxygen, and selected nutrients.

DESCRIPTION: This report integrated and combined specific circulation data from three years of data collection. Primary measurements included satellite thermal imagery; coastal, shelf, and oceanic winds; coastal water levels; regional hydrography; and subsurface currents and temperatures. Infrared satellite imagery employed in this study was provided by the TIROS-N/NOAA-6 spacecraft's advanced very high resolution radiometer and an older very high resolution radiometer aboard NOAA-3/4/5. Processing these data involved calibration, navigation rectification, and data base compilation. Hydrographic data were obtained during a series of cruises conducted in the South Atlantic Bight in 1978 and 1979. Six cross-shelf sections between Cape Canaveral, Florida and Cape Fear, North Carolina were sampled for

conductivity/temperature/depth, chlorophyll *a*, dissolved oxygen, temperature, and nutrients. Current meter moorings were deployed in cross-shelf transects off the Georgia Embayment and Blake Plateau. Three moorings were deployed off Savannah, Georgia at the 75-, 45-, and 30-m isobaths with current meters located 17 m from the surface and 3 m above the bottom. Another three moorings, located off Cape Romain, South Carolina, were located at the 45-, 40-, and 30-m isobaths with current meters positioned 10 m below the surface, mid-water, and 3 m above the bottom. On Blake Plateau, five taut-wire current meter moorings were deployed along 30°N Lat from 27 August 1980 to 6 October 1981. The meters measured subsurface and near bottom currents at depths as great as 800 m. Additional arrays such as GABEX-I consisted of 25 taut-wire current meter moorings placed along constant isobaths in waters ranging from 15 to 75 m. Bottom pressure recorders, inverted echo sounders, and thermistor strings were included on some of these moorings. Other series of moorings were distributed along a cross-shelf transect on the Charleston Bump in water depths ranging from 28 to 75 m. Surface current trajectories were estimated using surface drifters released along various transects. Three drifter experiments were conducted: June and January 1979 and January 1980, off Cape Romain; and Cape Hatteras in 1980.

SIGNIFICANT CONCLUSIONS: The Gulf Stream and associated boundary features such as filaments, frontal or boundary eddies, and meanders are the major influences on South Atlantic Bight circulation. Variations in Gulf Stream patterns occur on time scales ranging from daily to seasonal. Seasonal cycles of vertical water column stratification were evident. Gulf Stream effects on circulation were most pronounced in outer shelf waters. Inner shelf circulation is affected mostly by atmospheric fronts, freshwater input, and tidal currents.

STUDY RESULTS: The Gulf Stream is the most significant forcing mechanism promoting South Atlantic Bight circulation. Associated boundary features such as meanders, filaments, and frontal eddies significantly affect shelf circulation. As it flows north the Gulf Stream parallels the continental slope. Despite the constant nature of the Gulf Stream axis, the edges exhibit considerable variability in the form of filaments, meanders, frontal or boundary eddies. These boundary features exert considerable influence on shelf circulation, transporting heat, mass, momentum, and nutrients. Meanders are lateral oscillations deflecting boundaries inshore (or offshore) 20 to 30 km. These lateral deflections are the result of long waves with periods ranging from 2 to 14 days. Crests from meander waves often drag a lens of warm Gulf Stream water along behind. The thickness of this lens varied with location being 15 to 20 m deep in the Georgia Embayment, 60 to 100 m deep north of the Charleston Bump in the Carolina Capes, and as deep as 600 m in the unbounded region off Cape Hatteras.

Wind induced circulation in the South Atlantic Bight was evident across the entire shelf. Principal wind systems are associated with mesoscale atmospheric pressure systems and fronts which traverse the area with a 2 to 14 day periodicity. On the inner shelf, higher frequency events such as sea breezes contribute ephemerally to circulation. Wind fields associated with major atmospheric fronts are similar across the entire area. Conversely, Gulf Stream events are migratory and influence successive downstream locations sequentially. Wind and tidal effects on inner shelf circulation are often superimposed on horizontal density gradients produced by estuarine discharges.

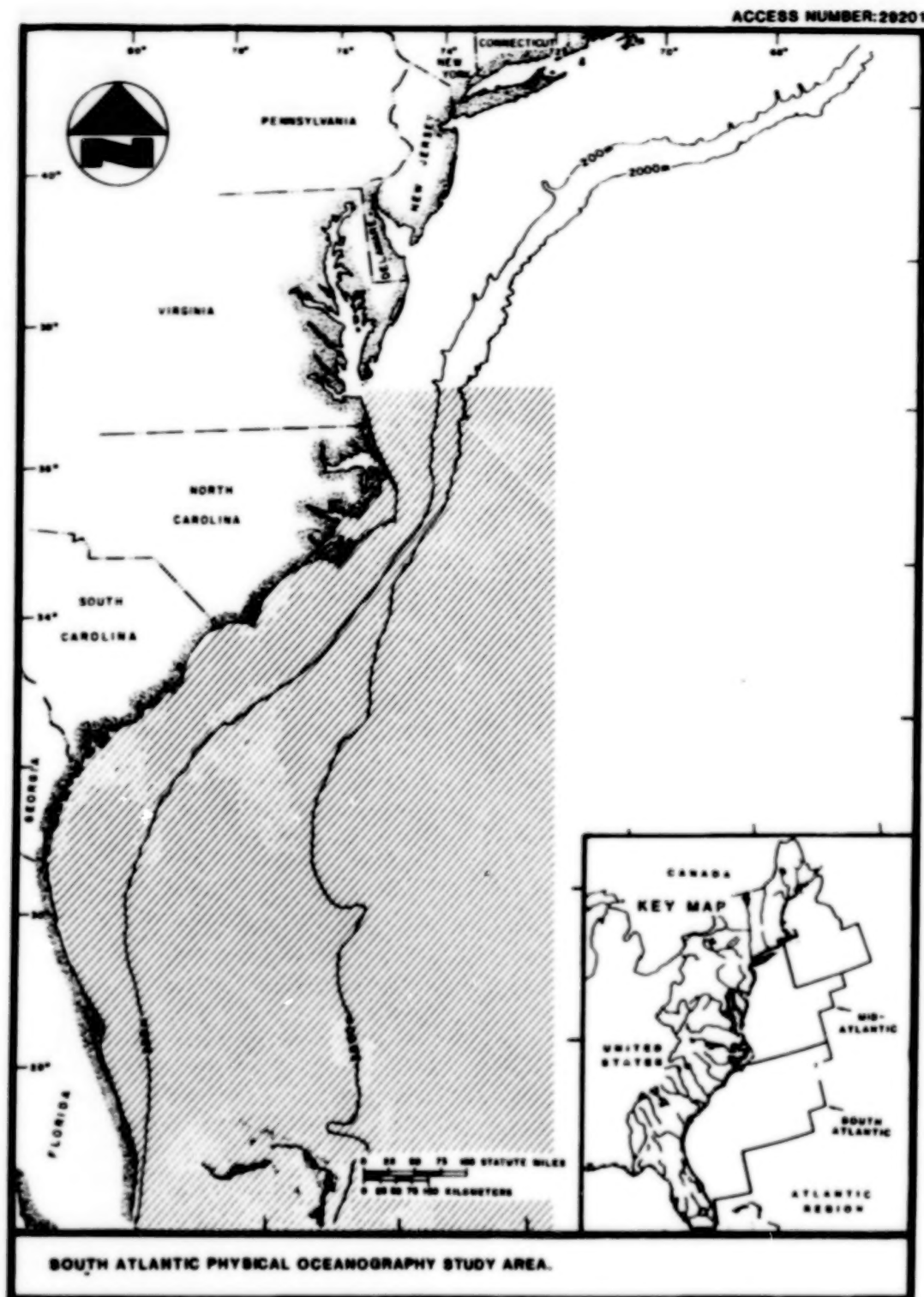
Tidal currents mostly affect inner and middle shelf waters where direct Gulf Stream influence is minimal. Tidal periodicities are rapid when compared to wind induced variability. The dominant tidal component is the semidiurnal lunar tide with a maximum tidal range and current on the Georgia continental shelf. Tides were much less of a factor on the Carolina shelf than on the Georgia shelf.

During summer, surface heating promotes vertical stratification of shelf waters. In fall, increased winds and cooler surface waters break down stratification and cause vertical mixing. By winter, the shelf waters are vertically uniform and horizontally stratified with the warmest waters being at or seaward of the shelf break. Inner shelf waters are increasingly colder from south to north. In spring, increased surface temperature and reduced mixing again promote vertical stratification. This cycle also influences a seasonal mean sea level cycle with lower than mean values in winter and higher than mean sea level in summer. Movements of surface and deeper Gulf Stream waters onto the shelf by boundary events occur during all seasons. During summer, upwelling associated with boundary events bring cooler waters onto the outer shelf thus the net heat flux is offshore. In winter, the net heat flux is onshore regardless of vertical or horizontal stratification.

STUDY PRODUCT(S): Science Applications, Inc. 1984. South Atlantic Physical Oceanography Study Final Report, Year Five. Vol. II: Technical Report. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. NTIS No. PB84187848. Contract No. 14-12-0001-29201. 224 pp.

Science Applications, Inc. 1984. South Atlantic Physical Oceanography Study Final Report, Year Five. Vol. I: Executive Summary. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. NTIS No. PB84187855. Contract No. 14-12-0001-29201. 13 pp.

**PI.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Analysis of Physical Oceanography Data Offshore North Carolina.

REPORT TITLE: Effects of Wind and Gulf Stream Events on the Currents off the Coast of North Carolina as it Relates to Oil Spill Risk Potential.

CONTRACT NUMBER(S): MMS: 14-12-0001-30152.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): Mid-Atlantic; South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1984.

COMPLETION DATE OF REPORT: August 1984.

COST(S): FY 1984: \$19,250; Cumulative Project Cost: \$19,250.

PROJECT MANAGER(S): F. Vukovich.

AFFILIATION: Research Triangle Institute.

ADDRESS: Research Triangle Park, North Carolina 27709.

PRINCIPAL INVESTIGATOR(S)*: B. Crissman, G. Janowitz, L. Pietrafesa, F. Vukovich, R. Weisberg.

KEY WORDS: Mid-Atlantic; South Atlantic; North Carolina; Virginia; physical oceanography; Gulf Stream; wind; currents; wind forcing; oil spill; risk assessment; modeling; Cape Hatteras; Cape Romain.

BACKGROUND: The U.S. Department of the Interior (USDOI) and State of North Carolina approved a Memorandum of Understanding (MOU) regarding the scheduled June 1983 South Atlantic lease offering. In the MOU, the USDOI agreed to fund a synthesis study of certain oceanographic and meteorological data sets available through the State of North Carolina. This study investigated potential effects of wind induced currents and/or Gulf Stream events on the overall current regime off the North Carolina coast because these factors were not completely understood and could affect oil spill transport in that region.

OBJECTIVES: (1) To examine currents offshore of North Carolina related to wind driven and Gulf Stream frontal event effects from existing data sets; and (2) To examine relationships of these factors to oil spill risk assessment and potential differences between actually existing flow fields and those predicted by the Minerals Management Service (MMS) Oil Spill Risk Model.

DESCRIPTION: Moored current meter, satellite very high resolution radiometer, satellite synthetic aperture radar, hydrographic, coastal zone color scanner and surface drifter data sets were collected for the period 15 March to 4 May 1979. The data sets were analyzed to determine potential effects of wind induced currents and/or Gulf Stream frontal events on North Carolina offshore currents. The report includes discussions and correlations of nearshore and offshore currents and penetration of Virginia coastal waters south of Cape Hatteras. The case study examined currents offshore of North Carolina when a series of waveforms existed on the western Gulf Stream boundary, in the region between 31 to 36°N Lat and 74 to 80°W Long (southeast of Raleigh and Onslow Bays, NC), during the period 15 March to 4 May 1979. These factors were

examined in relationship to oil spill risk assessment and potential differences between flow fields that actually exist and those predicted by the MMS Oil Spill Risk Model.

SIGNIFICANT CONCLUSIONS: The study demonstrated that marked differences can occur between observed and predicted flow fields. Gulf Stream frontal events, which are not considered in the MMS model, can markedly affect flow in the outer shelf region. The case study predicted flow fields that had a water parcel move off the shelf into the deep ocean when in fact, observed fields had the water parcel impact the coast.

STUDY RESULTS: Near surface currents off the North Carolina coast are affected by: (1) direct wind forcing; (2) interior currents (slope currents) set up by convergence of wind driven current due to the presence of lateral boundaries; and (3) existing background currents (e.g., the Gulf Stream). Present MMS modeling efforts attempt to account for direct wind driven currents and background currents but do not consider slope currents. Slope currents reflect the past history of alongshore wind stress components and add directly with direct wind driven currents at the sea surface.

Dynamical nearshore current regimes in Onslow Bay, North Carolina fall into two classes: (1) inshore of the 50-m isobath strongly correlated to and dominated by wind; and (2) offshore of the 75-m isobath, at 17-m depth, resulting from Gulf Stream phenomena (e.g., filament formation, meandering, and wave propagation) along the front.

A sinusoidal waveform (wavelength, 270 km; amplitude, 70 km) was first observed on the western Gulf Stream boundary off Cape Romain on 9 March. On 20 March, satellite data showed two waveforms on the western Gulf Stream boundary southeast of Long and Onslow Bays. The southernmost waveform exhibited thermal patterns suggesting warm water had been advected behind the wave, forming a warm filament. By 26 to 28 March, a wave train existed on the western boundary from off Long Bay to Raleigh Bay, with up to three wave troughs (average wavelength, 200 km; amplitude 50 km). The perturbation moved downstream at about 42 cm sec^{-1} average speed. On 6 April, a large warm filament (275 km long in northeast to southwest direction, and 30 km in northwest to southeast direction) was observed offshore from Long and Onslow Bays and persisted for about 30 days.

From 6 to 23 March, winds were predominantly from the north, northeast, or northwest. For the remainder of the period to 4 May, winds were from the southern sector. Persistent north sector winds during the first half of the study period was probably the cause of intrusion of Virginia coastal waters southward of Cape Hatteras.

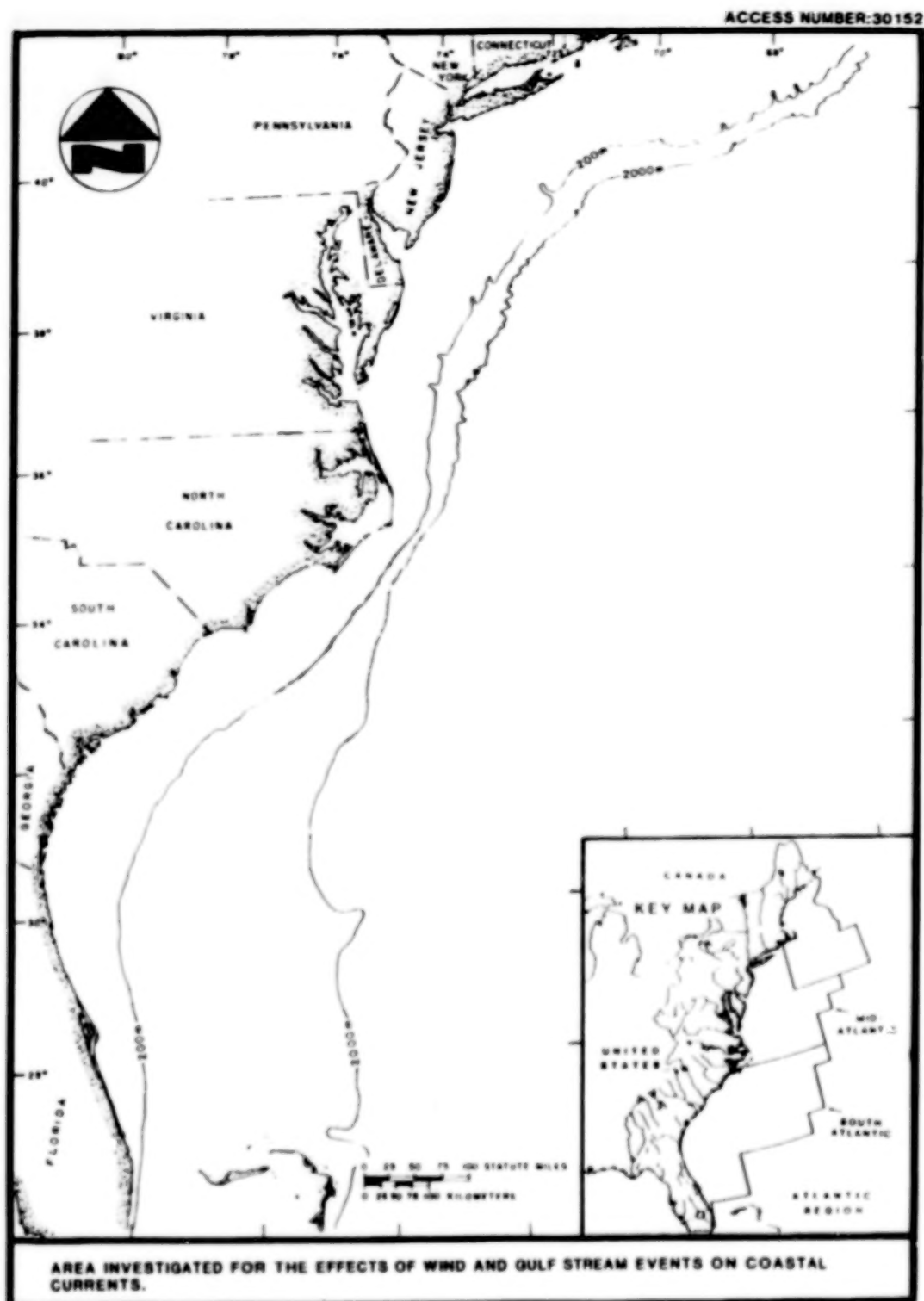
For the period 2 to 9 April, MMS predictions were on the same order of the observed net displacement of a parcel of water. Differences between direct wind driven current (as modeled by the MMS using Cape Hatteras wind data) and combined wind driven and slope currents occurred between 12 to 16 April, both in magnitude and direction for net displacement of a parcel. Observations placed the parcel on the coast, while MMS predictions placed the parcel in deeper water. The conclusion is that proper incorporation of time varying slope currents into modeling of parcel trajectories is imperative to obtain realistic risk analysis.

Apart from wind driven currents, the Gulf Stream provides background current off the North Carolina coast. Gulf Stream frontal events provide omnipresent initialization of offshore, time varying boundary. Frontal filaments and growing meanders, with time scales of several days to two weeks,

provide a mechanism to bring offshore waters onshore. Because these are dominant coastal features, initial conditions for movement of an oil spill will be provided by these features which can advect enormous amounts of water and contaminants onshore to the coast.

STUDY PRODUCT(S): Vukovich, F. M., B. W. Crissman, L. J. Pietrafesa, G. S. Janowitz, and R. H. Weisberg. 1984. Effects of Wind and Gulf Stream Events on the Currents off the Coast of North Carolina as it Relates to Oil Spill Risk Potential. A final report by Research Triangle Institute and the Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Region, Vienna, VA. Contract No. 14-12-0001-30152. 70 pp.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



VIII **SOCIOECONOMICS**

Socioeconomic studies characterize complex interactions between processes associated with oil and gas activity and the economic, social, and cultural systems of coastal residents.

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STUDY TITLE: Summary and Analysis of Cultural Resources Information on the Continental Shelf from Cape Hatteras, North Carolina, to Key West, Florida.

REPORT TITLE: A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West. Vols. I through IV.

CONTRACT NUMBER(S): BLM: CT8-40.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): South Atlantic.

FISCAL YEAR(S) OF PROJECT FUNDING: 1978; 1979; 1981.

COMPLETION DATE OF REPORT: June 1981.

COST(S): FY 1978: \$186,453; FY 1979: \$6,682; FY 1981: \$28,582;
Cumulative Project Cost: \$221,717.

PROJECT MANAGER(S): D. Stanczuk.

AFFILIATION: Science Applications, Inc.

ADDRESS: 1764 Old Meadow Lane, Suite 400, McLean, Virginia 22102.

PRINCIPAL INVESTIGATOR(S)*: M. Ahearn, J. Baskin, J. Custer, W. Gardner, S. Gluckman, R. Hansen, G. Haines, A. Hine, D. Koshi-Karrel, J. Milliman, L. Rappelye, T. Thompson, S. Webb.

KEY WORDS: South Atlantic; Georgia; South Carolina; North Carolina; Florida; cultural resources; literature review; shelf; sediment; currents; Cape Hatteras; archeology.

BACKGROUND: Cultural resources are protected and managed by a congressional mandate set forth in the National Environmental Policy Act of 1969, and the Archeological and Historic Preservation Act of 1974. In response to impending oil and gas exploration on the Outer Continental Shelf (OCS) off the southeastern United States, the U.S. Department of the Interior funded a survey of the origin, distribution, and recoverability of cultural resources (i.e., archeological sites and shipwrecks) in this area.

OBJECTIVES: (1) To combine physical environmental and archeological information to predict distribution, location, and concentration of archeological sites and shipwrecks; and (2) To use the above information in developing workable management schemes.

DESCRIPTION: A comprehensive review of existing data related to the past and present physical environment, prehistoric archeology, and shipping off the southeastern United States (Cape Hatteras, North Carolina to Key West, Florida) was completed. Information sources included computerized bibliographies and public and private libraries. Archeological and paleontological data in museum and private collections were examined. Interviews were conducted with researchers, museum curators, State and Federal officials, salvage operators, recreational archeologists, and divers.

SIGNIFICANT CONCLUSIONS: The shelf off the Georgia and South Carolina coasts had the highest potential for prehistoric habitation. A new sea-level curve was derived from new and existing data.

The highest density for shipwrecks occurred off Cape Hatteras, and southern Florida. These areas were considered in developing management zones and determining the intensity of pre-exploration archeological surveys.

STUDY RESULTS: Sedimentary characteristics (composition, load, and mobility) and water movements were considered important in preserving, destroying, or moving various artifacts. Three general provinces were delimited for the region: North Carolina (south of Cape Hatteras) which had thin unconsolidated sediment cover and high wave energy; South Carolina and Georgia which had the thickest sediment deposits due to shelf width, fluvial inputs and low wave energy; and the carbonate province of southern Florida and the Florida Keys which included a narrow shelf, coral reefs, and karst topography.

Paleo-rivers on the submerged shelf were likely locations for prehistoric human habitation during exposed periods (Pleistocene and Holocene). Rivers provided important lithic materials and sources of freshwater and attracted game animals. Several present-day coastal plain and piedmont rivers exist on the submerged shelf off North Carolina (i.e., White Oak and Cape Fear). The Santee River has been traced onto the shelf off South Carolina. The Georgia OCS was traversed by the Savannah and Altamaha Rivers. In northern Florida, the St. Johns and St. Marys Rivers extended onto the shelf.

Whether prehistoric man ever inhabited areas on the emergent shelf is not directly discernable, but judgements can be made using information concerning availability and location of required resources. Certain lithic materials were critical to Paleoindian cultures; cryptocrystalline rock was especially important in tool making. Population densities decreased as the distance from the suitable rock source increased. Many river systems draining the piedmont contained necessary lithic materials. Paleoindian populations approached the present day shoreline from the piedmont; by the time the coastal plain became inhabited, sea level was within a few meters of present day levels. A new sea level curve for the continental shelf south of Cape Hatteras was proposed. The new curve showed the lowest sea level at 60 m below present. The actual shelf area available to late Pleistocene-early Holocene man was similar to that determined from previous curves, but the duration of potential habitation was shorter. Man could have lived near the shelf edge for 3,000 years, compared to estimates of 11,000 years based on previous sea level curves.

Cape Hatteras and southern Florida contain the highest densities of shipwrecks. The highest shipwreck concentrations occur along the shoals of Cape Hatteras, Cape Lookout, and Cape Fear. Over 500 shipwreck sites were documented for southern Florida. Sketchy records, especially for 16th and 17th centuries, preclude accurate evaluation of shipwreck archeology from the Florida Keys. Most shipwrecks along the Georgia and South Carolina coasts occur inshore of the 20-m isobath.

Expected impacts from OCS oil and gas activities will vary according to type of operation and where it is focused. Three areas of concern include: (1) offshore waters where drilling and monobuoy terminal construction would occur; (2) inshore waters which will be traversed by pipelines; and (3) coastal waters where storage, pumping, and support facilities would be built.

The synthesized data were used to develop management schemes which would protect, identify, and enhance cultural resources. The prehistoric archeological model was based on distribution of environmental variables and how they might act to preserve, destroy, or concentrate artifacts. Three

sensitivity zones were combined into two management zones. Management Zone I consisted of the 12,000-year shoreline along the South Carolina and Georgia coasts. Management Zone II encompassed the area within the 16,000-year shoreline. Shipwreck sensitivity zones were designated inshore of the 20-m isobath off North Carolina and Florida.

Archaeological surveys should employ side-scan sonar, magnetometer, and subbottom profiling. Underwater video should be used in Management Zone I. Line spacing for towed instruments should vary with management zones.

STUDY PRODUCT(S): Science Applications, Inc. 1981. A Cultural Resource Survey of the Continental Shelf from Cape Hatteras to Key West. A final report for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Vol. I (Introduction and Physical Environment) - NTIS No. PB82138215; Vol. II (Prehistoric Archaeology) - NTIS No. PB82138223; Vol. III (Appendices) - NTIS No. PB82138231; Vol. IV (Conclusions and Recommendations) - NTIS No. PB82138249. Contract No. AA551-CT8-40.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*



STUDY TITLE: Assessment of Space and Use Conflicts on the U.S. Outer Continental Shelf Between Oil and Gas Industry and Commercial and Recreational Fishermen.

REPORT TITLE: Assessment of Space and Use Conflicts between the Fishing and Oil Industries. Vols. I through V.

CONTRACT NUMBER(S): BLM: CT9-26; MMS: 14-12-0001-29167.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): All.

FISCAL YEAR(S) OF PROJECT FUNDING: 1979.

COMPLETION DATE OF REPORT: January 1981.

COST(S): FY 1979: \$334,467; Cumulative Project Cost: \$334,467.

PROJECT MANAGER(S): B. Ingram.

AFFILIATION: Centaur Associates, Inc.

ADDRESS: 1120 Connecticut Avenue, N.W., Suite 465, Washington, D.C. 20036.

PRINCIPAL INVESTIGATOR(S)*: F. Proschaska, M. Roessler, D. Tabb.

KEY WORDS: North Atlantic; Mid-Atlantic; South Atlantic; Eastern Gulf; Central Gulf; Western Gulf; Southern California; Central and Northern California; Gulf of Alaska; Kodiak; Cook Inlet; Shumagin; North Aleutian Basin; St. George Basin; Navarin Basin; St. Matthew Hall; Norton Basin; Hope Basin; Barrow Arch; Diapir Field; socioeconomics; literature review; modeling; commercial fishing.

BACKGROUND: Resources present on the U.S. Outer Continental Shelf (OCS) have traditionally been utilized primarily by commercial and recreational fishing interests. With increased oil and gas activities on the OCS, space and use interactions between the two industries are inevitable. To assess the degree that oil and gas operations conflict with fishing activities, the Bureau of Land Management supported a comprehensive survey of ongoing and potential conflicts.

OBJECTIVES: (1) To review historical conflicts between OCS oil and fishing industries; (2) To identify potential and ongoing fishing gear type vs. oil structure conflicts; (3) To develop a predictive catch loss model due to space loss by OCS oil structures; and (4) To assess the ability of particular harbors to accommodate oil support vessels and staging operations.

DESCRIPTION: The geographical scope of this study included the Atlantic, Gulf of Mexico, and California OCS lease sale regions. Site visits were made to 30 ports. Each port was evaluated for physical characteristics (i.e., depth, basin size onshore acreage), use by the fishing industry, and

potential to service as a existing constraints and issues in the harbor and availability of berthing space and marine service facilities (i.e., yards, mechanics, electronics, technicians). Literature reviews were conducted to provide descriptions of presently used fishing gear types and OCS oil structures and technologies. To predict potential catch loss due to area by oil structures, a Markovian statistical model was used. The model predicted the probability of catching fishes which move randomly between a buffer (no-fishing zone near the structure) zone and adjacent fishable zones. The relative catch collected under various development alternatives and with various assumed parameters was compared with relative catch collected with no loss. Results of the expected catch quantity and value can be compared to estimate expected loss. Monte Carlo techniques were used to estimate the probabilistic distribution of impacts as a function of a large number of uncertain variables. Estimates were made of component and total cost and revenue impacts associated with catch loss and berthing, and repair cost impacts.

SIGNIFICANT CONCLUSIONS: Otter trawls, bottom dredges, and purse seines were most likely to conflict with oil structures. Submerged wellheads, pipelines, and other subsea structures were most hazardous for these gear types. Structure-related debris and activities caused more problems to fishermen than the actual oil structures. Most significant projected catch losses were related to otter trawl fisheries in the North Atlantic, Mid-Atlantic, and Eastern Gulf of Mexico regions. Fishery expansion was not expected to be significant in most areas. Competition for labor between the two industries was not appreciable; in some areas there may be a working relationship.

STUDY RESULTS: Fishing gear most likely to conflict with oil structures included dredges, gill nets, hook-and-line, longlines, mid-water and otter trawls, pots and traps, and purse seines. Gear types least likely to conflict with oil structures were bag, butterfly, cast, dip, fyke, stop, and trammel nets, and hoes, rakes, scapes, weirs. Otter trawls, offshore dredges, and purse seines were considered most affected. Drift gear such as gill nets or longlines may be deployed very close to the down current side of an oil structure. Hook-and-line, commercial diving, and spearfishing operations may take place right under a surface structure depending on weather and sea conditions. Gear used generally depends on the target species and local conditions.

Surface structures include fixed, anchored, or tethered platforms, drillships, and drill units. Subsurface structures include pipelines, subsea completions, suspended wellheads, and guyed towers. Freestanding steel jacket platforms and other vertical structures require the least area (5,300 to 14,000 m²). Catenary moored floating production facilities occupy 0.35 to 0.65 km². The type of structure used depends on water depth, surficial sedimentary characteristics, subbottom structural and tectonic characteristics, and oceanographic and meteorological conditions.

Subsurface structures present the most problem for demersal gear types. The most significant problem in most areas arises from debris left on the bottom from pipeline construction, wellheads, platforms, and supply vessels. California and Gulf of Mexico fishermen cited debris (mostly steel cable and metal scraps) as a significant hazard. In some areas, charting of obstructions has been undertaken to avoid gear loss. Total gear loss due to OCS structures by shrimpers in the Gulf of Mexico (Louisiana) was estimated at \$1,848,944 for inshore waters and \$1,481,225 for offshore waters. Collisions between fishing vessels and OCS structures numbered 31 between 1963 and 1978. The average damage per fishing vessel as a result of the accidents was \$14,000. Average damage to structures was \$3,480. Expansion of many fisheries was not expected, primarily because most target species are near or have reached maximum sustainable yields. Groundfish expansion may be expected for the South Atlantic region resulting in 50 new vessels by 1990. Expected

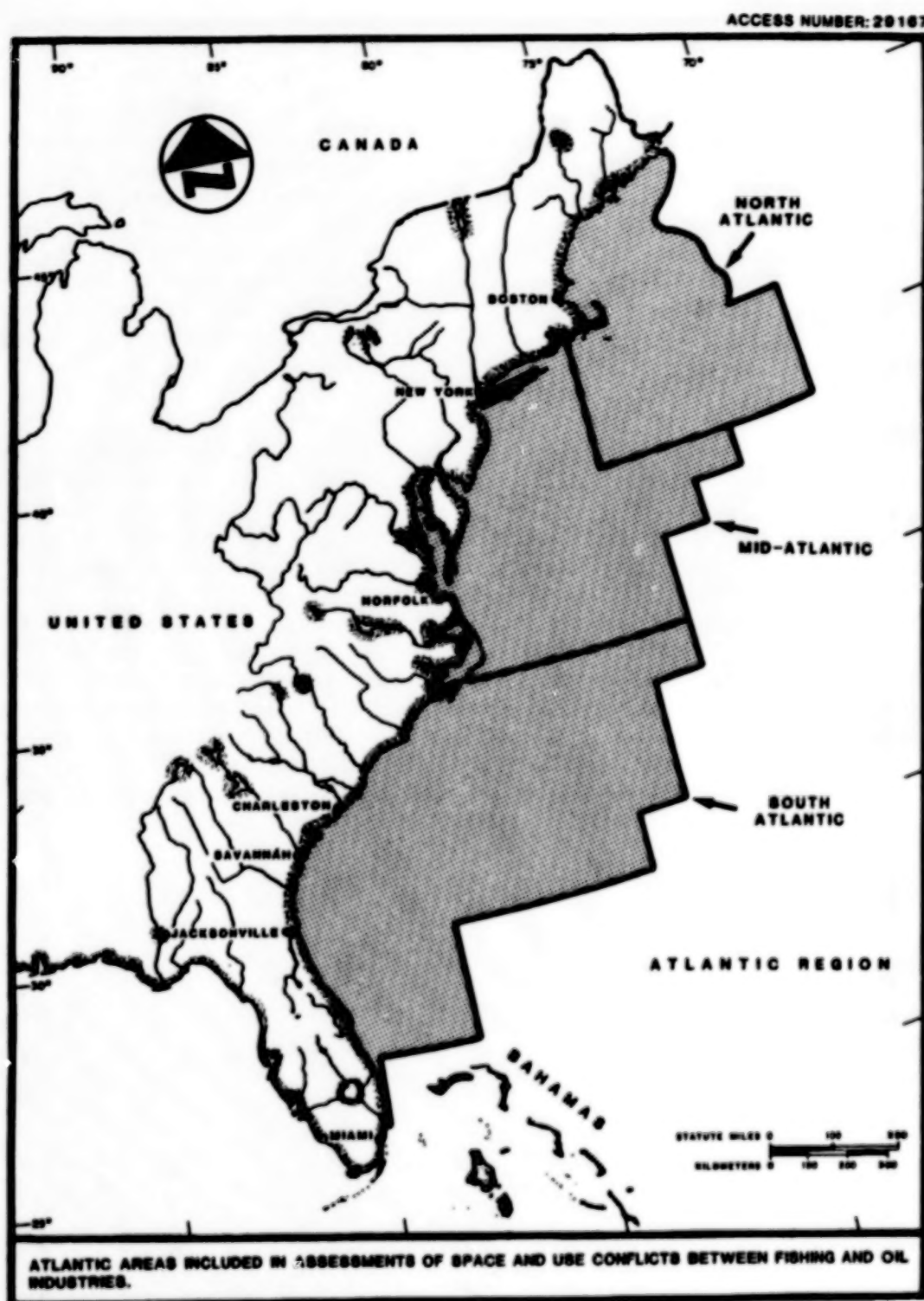
growth in the hake fishery of Northern California is 20 new vessels by 1990. Little expansion was expected for other areas.

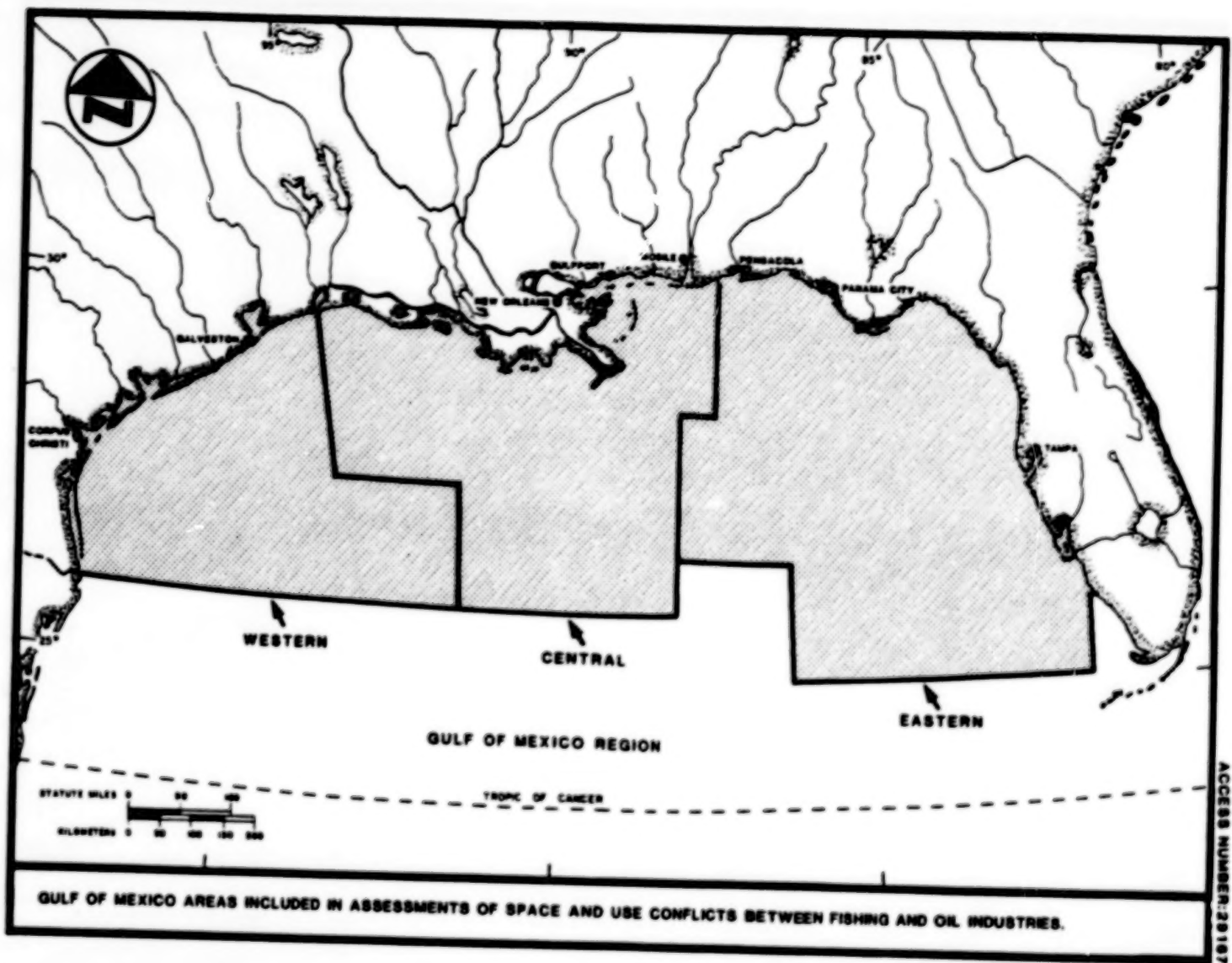
Projections concerning the ability of certain fishing harbors to accommodate OCS support vessels and staging operations indicate few problems. Gloucester, Massachusetts harbor would be congested due to existing fishing activities; however, availability of labor and onshore acreage would not present problems. In most areas, competition for labor (captains and deck hands) would be minimal owing to comparable salaries offered by both industries. Licensed captains (ocean operators) may be lured away from the charter boat trade in some areas. In North Carolina and Texas, the OCS support operations are an advantage to part-time commercial fisherman seeking work during off seasons. Marine facilities were not a problem in most harbors. Many processing plants provide berthing and other space to fishermen. Some California harbors (Bodega Bay and Moss Landing) are too shallow to support anything but small OCS crewboats. Santa Barbara is often severely congested due to heavy recreational traffic. Fort Bragg is shallow and seasonally congested by fishing vessels.

Catch loss simulations predicted dollar losses after 30 years in the sea scallop fishery of the North Atlantic and Mid-Atlantic regions to be \$33,195 and \$31,225, respectively in 1981 dollars. For the Eastern Gulf of Mexico region, shrimp fishery mean annual dollar loss was projected at \$108,176 in 1981 dollars. In the Mid-Atlantic, percent fishing area loss averaged 2.6%. Eastern Gulf of Mexico shrimp fishery areal loss was expected to be 2.4% after 30 years. Southern California trawl fisheries for sole and rockfish were expected to lose 6.9 and 6.0% of the fishable area, respectively.

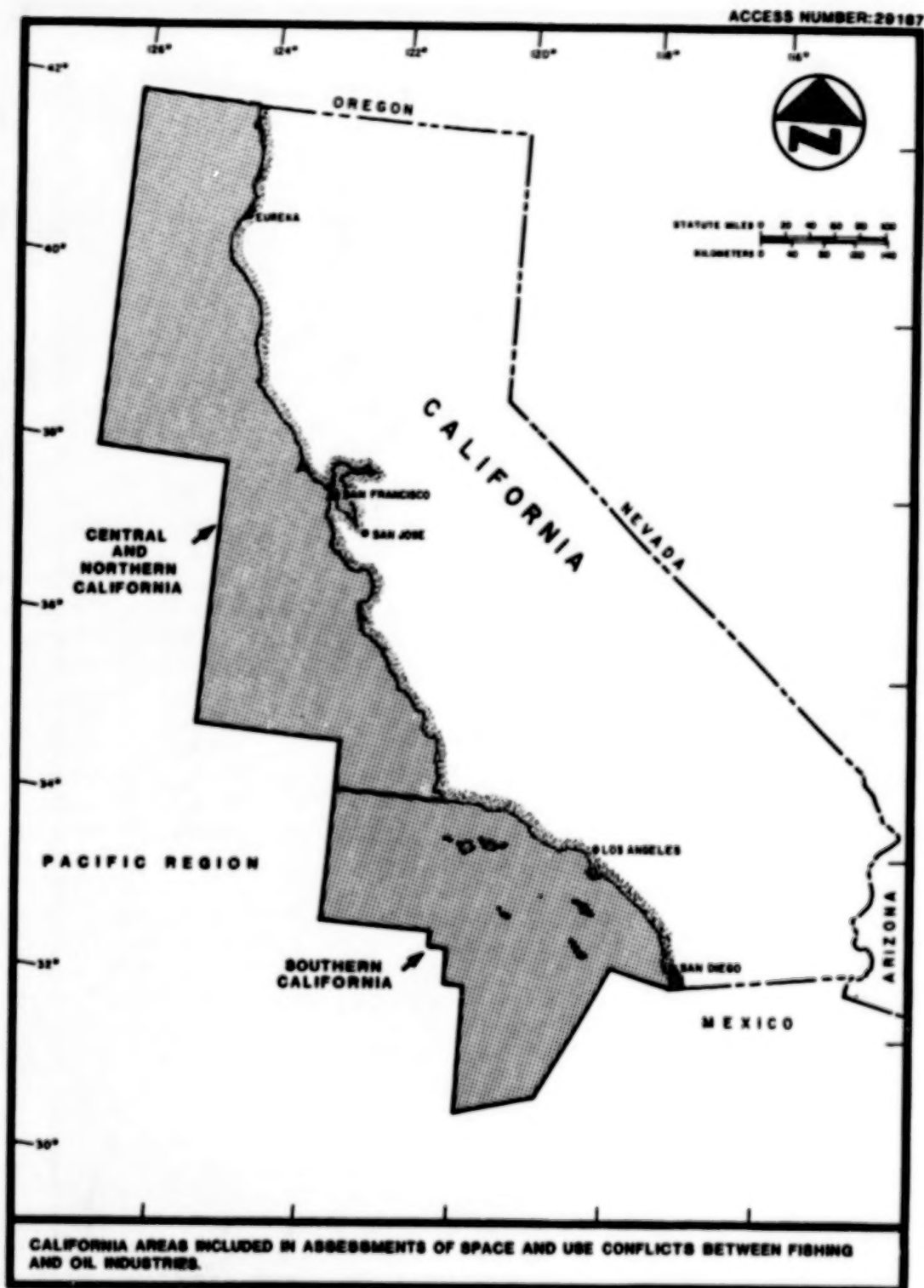
STUDY PRODUCT(S): Centaur Associates, Inc. 1981. Assessment of Space and Use Conflicts between the Fishing and Oil Industries. A final report by Dames and Moore for the U.S. Department of the Interior, Bureau of Land Management Atlantic OCS Office, New York, NY. Set - NTIS No. PB81215956; Vol. I (Interactions between Fishing Gear and Oil Structures) - NTIS No. PB81215964; Vol. II (Engineering Assessment) - NTIS No. PB81215972; Vol. III (Historical Interactions between the Fishing and Offshore Oil and Gas Industries) - NTIS No. PB81215980; Vol. IV (Catch Loss Model) - NTIS No. PB81215998; Vol. V (Potential Port Impacts on Space, Labor, Marine Facilities, and Other Inputs) - NTIS No. PB81216004. Contract No. AA551-CT9-26.

**P.I.'s affiliation may be different than that listed for Project Manager(s).*





Access Number: 29167



STUDY TITLE: Alternative Modes of Transporting OCS-Produced Oil and Natural Gas.

REPORT TITLE: Study of Alternative Modes for Transporting OCS-Produced Oil and Natural Gas.

CONTRACT NUMBER(S): BLM: CT2-41; MMS: 14-12-0001-29199.

SPONSORING OCS REGION: Atlantic.

APPLICABLE PLANNING AREA(S): All.

FISCAL YEAR(S) OF PROJECT FUNDING: 1982.

COMPLETION DATE OF REPORT: August 1983.

COST(S): FY 1982: \$150,000; Cumulative Project Cost: \$150,000.

PROJECT MANAGER(S): J. Carboni.

AFFILIATION: Policy Planning and Evaluation, Inc.

ADDRESS: 8301 Greensboro Drive, Suite 460, McLean, Virginia 22102.

PRINCIPAL INVESTIGATOR(S)* E. Burrows, J. Carboni, J. Dickson, R. DiNapoli, J. Singh.

KEY WORDS: North Atlantic; Mid-Atlantic; South Atlantic; Eastern Gulf; Central Gulf; Western Gulf; Southern California; Central and Northern California; Gulf of Alaska; Kodiak; Cook Inlet; Shumagin; North Aleutian Basin; St. George Basin; St. Matthew Hall; Navarin Basin; Norton Basin; Hope Basin; Barrow Arch; Diapir Field; transportation economics; alternatives; hydrocarbons; transportation; constraints; literature review; model; pipeline.

BACKGROUND: Early estimates of potential hydrocarbon reserves in the Atlantic Outer Continental Shelf (OCS) region indicated that the region might be a significant mineral resource area. The Minerals Management Service (MMS), as the agency responsible for offshore leasing and supervisory activities, contracted for this investigation of alternative transportation methods for potential oil and gas produced in the Atlantic leasing area.

OBJECTIVES: (1) To identify alternative modes of transporting oil and natural gas; (2) To identify onshore and offshore facilities necessary for each mode, including those needed for offshore conversion of natural gas and offshore storage, treatment, and loading of oil; (3) To determine technological feasibility, and regulatory and environmental constraints associated with identified transportation modes; (4) To determine the required capital and operating costs of facilities and unit costs of produced and transported products for each transporting mode; and (5) To conduct an economic analysis of alternative modes.

DESCRIPTION: The study reviewed existing and expected future methods of transporting oil and gas. Technologies appropriate to the Atlantic offshore were selected and reviewed from existing literature and contact with firms operating in similar conditions (e.g., the North Sea and Mediterranean Sea). Environmental and regulatory aspects and constraints of reviewed technologies were investigated. Process vendors and contractors provided capital and operating cost data. Oil and gas exploration, development, and production costs were provided by MMS. All cost variables were projected to 1990+. Market analyses were performed to assess future markets and prices for

products. The economic analysis included: (1) selection of equation variables such as discount rate from Federal Energy Regulatory Commission records, economic life, depreciation from applicable tax laws, debt/equity ratios, and taxes that apply to each technology; and (2) construction of a net present value (NPV) model to calculate value (net loss or gain) for operating a particular transportation mode over a range of assumptions dealing with parameters such as operating costs, price, discount rate, distance from shore, gas composition, water depth, and field size.

SIGNIFICANT CONCLUSIONS: Comparative analysis of existing and expected future transportation technologies concluded that pipelines have the greatest NPV for all base case scenarios. Pipelines, regulated as common carriers, have lower base discount rates than unregulated methanol plants, liquid natural gas (LNG) plants, and oil tankers. Recovery of capital for pipeline-transmitted products are insured by tariff, thus reducing financial risks and lowering the discount rate. Lack of commercial experience with methanol or LNG processing plants on floating platforms, particularly in exposed deepwater environments, assumes large contingency fund requirements on these technologies.

STUDY RESULTS: The study investigated alternative methods of transporting oil and natural gas from the Atlantic OCS. Technical analyses were conducted for pipelines; oil transportation by tanker; and natural gas conversion to LNG, methanol, ammonia, and electricity. Economic analyses were conducted for all methods except conversion of natural gas to ammonia and electricity which both have unresolved technical problems and are of low commercial interest.

Oil and gas pipelines and shuttle tankers have all been used to transport oil and gas from offshore wells. Pipelines have been placed in water depths up to 600 m (2,000 ft). Technological advances will allow placement of up to 10 in. pipe to 4,000 m (13,000 ft) by 1990. Development of adequate mooring systems is the primary constraint to using oil tankers to transport oil in the Atlantic OCS.

The feasibility of converting natural gas to methanol on floating structures was evaluated. The technological problem is to reduce motion on the conversion vessel, because motion affects the efficiency of acid gas removal and distillation. Fewer studies have been conducted concerning conversion of natural gas to LNG on floating structures. Technological problems exist with storage and handling of LNG which requires extremely cold temperatures (-160°C). However, LNG is a promising solution for gas transportation because less fuel is lost in conversion, conversion takes place at low temperature and pressure, and no open fires are required for conversion. Conversions of natural gas to ammonia and electricity have received little recent investigation and have technological problems. Ammonia requires storage and handling under either cryogenic or pressurized conditions. For electricity, total power loss from transmission via submerged cable would amount to more than two-thirds of the energy available in natural gas.

Relevant economic and financial parameters for each transportation mode were reviewed, including appropriate discount rate, estimated market prices in the 1990 to 2000 time frame, allowable depreciation methods, tax rates, expected inflation rates, and number of operating days per year. An NPV model was developed to discount the anticipated costs and revenues streams, and to calculate per unit cost of transportation for each transportation mode.

In a comparative analysis, pipelines have the greatest NPV for all base case scenarios. The assumed low discount rates and contingency funds for pipelines compared to other alternatives

influenced the results. Pipelines are regulated as common carriers and, as a result, recovery of capital is insured by tariff, thus reducing financial risks and lowering discount rates. Methanol plants, LNG plants, and oil tankers have financial requirements similar to unregulated chemical and oil companies with no regulatory protection from price variation. Larger contingency funds are required for development of processing plants on floating platforms, particularly in exposed deepwater environments because of a lack of commercial experience.

STUDY PRODUCT(S): Policy Planning and Evaluation, Inc. 1983. Study of Alternative Modes for Transporting OCS-Produced Oil and Natural Gas. A final report for the U.S. Department of the Interior, Minerals Management Service Atlantic OCS Office, Vienna, VA. NTIS No. PB84140284. Contract No. 14-12-0001-29199. 333 pp.

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